SCHOOL SCIENCE AND MATHEMATICS

Vol. L — March, 1950 — Whole No. 437

ALBERT EINSTEIN

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Albert Einstein was born at Ulm, Germany, on March 14, 1879. When he was a year old, his father moved his family to Munich and started a small manufacturing business there. The business was successful and Albert's youth was that of a son of prosperous parents of cultured tastes and generous inclinations. In the family circle there were thoughtful discussions of important subjects, there was good music, and there were good books. Albert was given music lessons when he was very young and, in time, he became very proficient on the violin.

In school he was an excellent student in mathematics, fair in science, and poor in languages. Although he was not a bad boy, he resented discipline and was often under the displeasure of his teachers. When he entered junior high school, he came under the influence of an excellent teacher named Ruess who recognized Albert's genius, fed it with good leadership and great books, and guided the boy in his studies. Albert responded eagerly and entered into a new and delightful world of intellectual satisfactions. When he was fifteen years old, his father failed in business and moved from Germany into Italy. However, Albert was sent to a technical school in Switzerland. He was required to take an entrance examination; this he failed because of poor grades in languages and biology. In order to make up his deficiencies, he entered a preparatory school at Aarau in Switzerland. His experience here was a happy one and he was soon ready to enter the Swiss Federal Polytechnic School at Zurich.

Einstein was recognized as a good student in college, but his career was not a distinguished one. He sometimes cut classes, but so did many other students, and, in fact, there was no disposition on the

part of the school to compel constant attendance. Great stress was placed on examinations, and if a student chose to endanger his passing by sometimes being absent from class, that was his affair. However, Einstein was good enough in his courses that he was employed as a tutor by some of the other students. This employment helped pay his way through school, and even with this supplement to a small amount given to him by a relative, he had only enough to live very poorly.

Einstein wanted to be a teacher so that he could continue his studies and spend his life with books, schools, students, and ideas. After graduation he found a position as substitute teacher in a vocational school. He was a good teacher but when the regular teacher returned, he had to leave. For some time he was in poverty and despair, but he finally found employment in the Swiss Patent Office. The pay was not large but the work was so light that Einstein had many hours when he could study science and mathematics at his desk.

Soon after taking the patent office job, Einstein married Milvea Maritch whom he had known in college. That was in 1903.

About this time Einstein became interested in a famous experiment known all over the world as the Michaelson-Morley experiment. This was an experiment performed by two Americans in an effort to learn how fast the earth was moving with respect to the ether. The results were not at all what could have been expected, and no one had ever been able to explain the observed facts. The experiment had been done about sixteen years before Einstein became a clerk in the Swiss Patent Office. Many of the world's greatest scientists had tried to reduce the observed effects to agreement with accepted scientific information, but all in vain. At his desk in the patent office Einstein began to think about this experiment, bringing to bear his knowledge of science and mathematics and above all his ability to think clearly on fundamental truths. He spent about three years working on this problem. In 1905 he sent to a magazine, *Annals of Physics,* a paper containing his analysis and solution of the problem. This contained his special theory of relativity.

This theory was so new and radical that it set the whole world of scientists talking. Some thought he had done a great work; others thought he was hardly worthy of the name of scientist. His ideas bore up under close examination and gained wide attention and increasing acceptance.

As a result of this one paper, Einstein was made a professor of physics at the University of Zurich in Switzerland. Then invitations came from many other universities for him to join their faculties. He accepted a professorship at Prague. He continued to publish scientific

papers and his reputation spread and became firmly established. Everywhere he was now recognized as one of the world's great scientists. His old school, the Swiss Polytechnic at Zurich, offered him an attractive position and he accepted. Two years later he accepted an even more attractive position as research professor in the new Royal Prussian Academy of Science in Berlin. That was in 1912.

When Einstein moved from Zurich to Berlin, his wife and two children remained in Zurich. In a short time, Professor and Mrs. Einstein were divorced.

In Berlin Einstein devoted himself anew to research, not only because his tastes ran in that direction but also to avoid thinking about the horrors of the war which soon broke over the world. In 1915 he published his second great paper on relativity, his general relativity theory, and his fame became greater than ever. His position as one of the great scientists of all time was now secure.

In 1917 Einstein married his cousin Elsa. She had no great interest in science, but she understood the needs of a great genius. She prepared his favorite foods, kept them ready, and waited patiently until he remembered to come down to eat; she remembered to put money into his pockets when he started away on a trip; she turned away the crowds of curious persons who would have spoiled his working day; she saw to it that he got away for an occasional brief vacation; she remembered to buy strings for his violin so that he could have the relaxation and pleasure of his music.

In 1921 Einstein came to America for a visit. His principal purpose was to raise money for Jewish relief and education, but everywhere he went he was honored as a great man, not only by scientists who understood the significance of his discoveries, but also by the common people who understood only that here was one of the great men of all time.

Back home in Germany, Einstein found himself the victim of increasingly violent verbal attacks because he was a Jew. There was even danger that he would be killed. However, the violence finally abated, circumstances changed, and he survived.

In 1922 a great honor came to him. In that year he was awarded the Nobel prize for Physics. Along with the honor went a money award of some forty thousand dollars. This whole amount he gave to his divorced wife and their children in Switzerland. Following the winning of the Nobel award, there were invitations from all over the world to visit various learned societies and universities; books and magazine articles were written about him; there were offers of positions in leading universities all over the world. He accepted the invitation of the California Institute of Technology to spend some time there doing research with the scholars of that school.

In 1933 Hitler was master of Germany and was frankly and mercilessly persecuting all Jews, killing many. Einstein was then once more in America and decided not to return to Germany. He was offered a position at the Institute for Advanced Study at Princeton, New Jersey, and, after one more trip to Europe, he accepted the offer.

In order to explain certain phenomena of nature, scientists make use of the laws of gravitation or the theory of relativity. In order to explain other natural phenomena, they make use of quantum theory and other special theories. For years, Einstein has believed that one larger theory could be worked out that would satisfactorily explain a very wide range of phenomena, thus unifying a number of important natural laws. To this problem, he devoted his energies for a number of years. In January, 1950, it was announced that he had finally succeeded in working out the mathematical details of the unified field theory, as it is called. This contribution appears as a supplement to a new edition of his work, The Meaning of Relativity. It raises the scientist to even greater heights than those previously reached by him.

In 1936 Einstein became a citizen of the United States. In 1945 he retired from his position at the Institute for Advanced Study. Today he lives quietly and alone, Mrs. Einstein having died in 1936.

As one consequence of his theory of relativity, Einstein had proved that energy and mass are equivalent, the formula connecting the two being expressed in the now familiar formula $E=mc^2$. Here E represents the energy equivalent of a mass m and c is the velocity of light. For example, the energy equivalent of a gram of U235 is $1\times(3{,}000{,}000{,}000)^2$ ergs $=9{,}000{,}000{,}000{,}000{,}000{,}000$ ergs. During the second World War scientists of the principal countries involved in the conflict were frantically working to find a way to make use of this great source of power. Albert Einstein urged President Roosevelt to give scientists of America and those from friendly countries financial means to try to get this source of energy and make it available for winning the war. It was as a result of the appeal that America succeeded in making the atomic bomb. In this material way did Einstein partially repay America for having afforded him a refuge and the opportunity to pursue his researches in peace.

COLLEGE ENROLMENT

Enrolments in the nation's colleges and universities continued to show an increase in the face of a declining number of student veterans, according to a report released by Federal Security Administrator Oscar Ewing.

Total enrolment in the fall of 1949 stands at 2,456,000 students, as compared with 2,408,000 a year ago.

APPLICATIONS OF ATOMIC ENERGY TO THE BIOLOGICAL SCIENCES*

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"Atomic Energy" can quite modestly lay claim to being another of the wonders of Nature. Only recently has it been unveiled to the layman and to many scientists as one which may ultimately surpass the others when fully harnessed by Man.

As a biological scientist I cannot fully foresee its utility in other professional fields. However, I am quite certain that the nuclear physicist and others in the physical fields associated with basic atomic research anticipate a number of fundamental applications.

Ever since the beginning of time, the subject most interesting to Man has been the study of Man himself. This is particularly true of the biologist whose objective is the study of life with its complex of interacting biological processes and mechanisms. We would be correct in stating that the ultimate goal of the biologist is still far off, with but a few units of the puzzle pieced together with certainty.

As we all know, the great majority of what is known at present has been unearthed in relatively recent years. The advances of any one period of progress, particularly the present, can be correlated with the availability of new biological tools. The tool may be an instrument for precision measurement of any one of a number of internal or external environmental factors which interplay to control organ processes or functions. It may be a new method of chemical or biological assay for an unknown but specific substance which thereby is exposed as an essential one for the organism. Perhaps it may simply be a device for magnification, such as the compound and electronic microscopes, instruments which reveal previously unknown morphological details or a minute but important cellular inclusion.

The applications of Atomic Energy as a tool to aid both theoretical and practical studies in the fields of biological science are relatively unlimited and appear destined to ultimately contribute more than any of the earlier biological tools. The number of applications are limited only by the scope of the imagination exercised by the biologist. The variety of the "tracer" applications which has been just presented by Dr. Woodruff well indicate the ultimate utility with which Atomic Energy, in its various forms, can serve when peacefully harnessed by Man. Like any of the previous tools it will not be a cure-all or nullify the importance or need of those already in use.

* Presented at the Biology Section of the Central Association of Science and Mathematics Teachers, November 25, 1949.

In the short time allotted, it will be only possible to consider a few of the varied applications. For this reason it will be most profitable to note the various possible approaches, in general terms only, and subsequently consider a few specific applications emphasized in more detail.

All workers concentrating in the field of atomic energy and those, such as biologists, who hope to utilize it simply as a tool must be concerned with the effects of the various forms of ionizing radiations upon the growth and development of living organisms and their offspring. This type of radiation may be atomic matter in such forms as x-ray, neutrons protons and beta, gamma and alpha particles. The prime objective may be to secure toxicity data with respect to a given type of radiation. For example, such data are of interest to the physician and geneticist. To the former it is a concern of health, whether the irradiation be the result of accident or intentional in order to correct a tissue or organ that is functioning abnormally.

The botanist is utilizing x-ray and slow neutrons to irradiate plants and plant parts in an effort not only to understand the genetical responses but also the possibility of these radiations assisting the development of better plants and crops. In certain cases, with x-ray treatment it has been possible to accelerate the rate at which nature yields new "desirable" plant varieties.

The "tracer" application is unquestionably the most promising technique ever placed in the hands of the biologist. By use of either stable or unstable (radioactive) forms of the basic elements he is able to enter many of the physical, chemical and biochemical pathways in living organisms which previously were done with difficulty. The simplicity of "tagging" a constituent atom in the molecule of an important biochemical or an essential element has yielded data not otherwise obtainable. For example, the chemical methods for assaying a particular compound or element will only assure detection when the concentrations of it are of orders not less than one part in ten to one hundred million. With radioactive forms of the compound or element it becomes possible to detect concentrations as low as one part in a millionth billionth. Such chemical messengers can obviously aid the determination of the role and fate of particular substances or substrates mixed in the general metabolic pool.

Among the various isotopes available for biological studies, none offer as many possibilities as the tracer isotopes of carbon. "Organic chemistry" is the chemistry of carbon compounds and, with living organisms possessing a forty per cent carbon composition the applications of carbon isotopes to biological problems becomes obvious.

Of the five isotopes of carbon, the most promising of all is radioactive carbon-14, discovered by Ruben in 1940. It is now supplied in

reasonable quantities by Dr. Abersold and Dr. Woodruff's group at Oak Ridge. This isotope occurs in nature at a concentration of approximately 10^{-10} per cent and is in our own bodies at this same concentration. Since the only radiation emitted by carbon-14 is a very weak beat particle which has little penetrating power, no real danger is connected with handling of carbon-14 materials in ordinary containers. The real danger lies in ingesting it in organic form. Following digestion, or assimilation it can become part of the body carbon in tissues, such as bone, in which little turnover of carbon occurs. This is magnified because the half-life of this isotope is approximately 5400 years. On the other hand, the long half-life is desirable from other standpoints. It does not limit one to short biological time studies, and once a compound is prepared it can be set on the shelf for future use without the possibility of either complete or substantial loss of radioactivity occurring.

The study of biology can also be accurately and simply defined as a study of the carbon cycle. Associated with this cycle are all of the important problems of man and individual animal organisms and their populations. The rewards for seeking a complete understanding of any organism are apparent—the maintenance of the organism at a maximum level of health, thereby assuring maximum longevity and productivity. Ultimately it would assure an efficient carbon cycle—one that is controllable by man. That man is completely dependent upon other organisms for his sustenance need not be emphasized. He is already under considerable pressure to understand and control the carbon cycle.

Carbon-14 is proving the most useful tool now available for study of the carbon cycle. It is being utilized by an ever increasing number of workers throughout the United States and foreign countries. For any research group, one of the first problems is the incorporation of the isotopic carbon into the particular substance or molecule to be studied. This can be accomplished by one or the other of two different methods. In certain cases may it be possible for the chemist to do the labeling in the laboratory. In many cases, the substance or molecule cannot be synthesized by the chemist. In such instances it is then possible to produce the tagged substance by means of biosynthesis. To do this the animal or plant that normally forms the required compound is fed carbon-14 forms of the required, molecular building-stones. After the biochemical laboratory of the organism has synthesized sufficient quantities, the labelled molecule or substance may be extracted from the tissues.

The Radiobiology Experiment Station, Division of Biology, Argonne National Laboratory is cooperating with the Isotopes Division at Oak Ridge in an effort to biosynthesize a wide variety of

carbon-14 labelled plant and animal products for use in fundamental biological investigations. This particular program of the Experiment Station is relatively young but sufficient progress has been made that we can now say with assurance that it is possible to produce radiocarbon forms of any of the organic compounds occurring in living organisms. Essentially this is accomplished by starting with the green plant. These are grown from seedlings in an atmosphere containing radioactive carbon dioxide. Through the process of photosynthesis the radioactive carbon is assimilated and thereby incorporated into

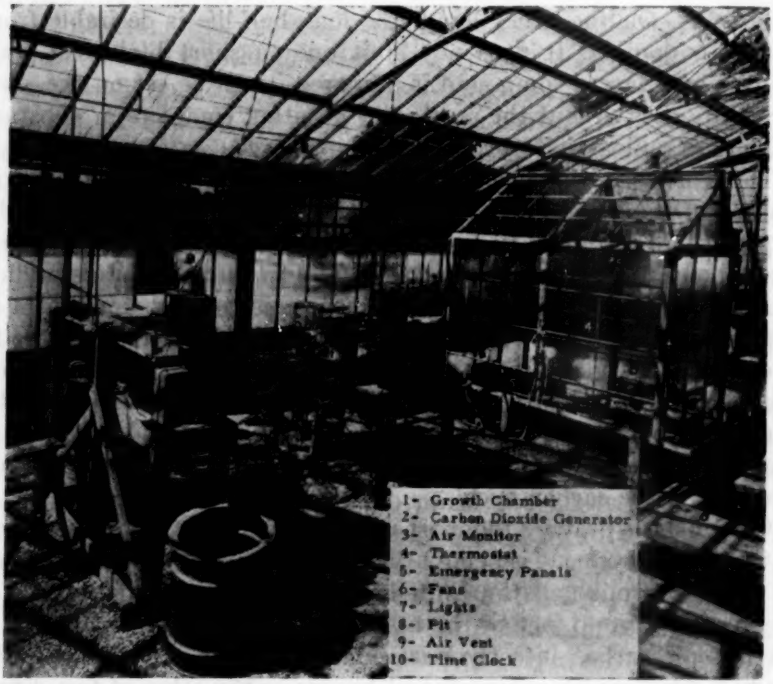

FIGURE 1. The nutriculture, plant growth-chamber developed at the Radiobiology Experiment Station, Division of Biology, Argonne National Laboratory for the biosynthesis of radioactive plants and plant products. The chamber has been particularly designed for use of radiocarbon which is assimilated as carbon dioxide in the process of photosynthesis. Numbers 1–10 indicate certain essential features of the system.

every organic compound synthesized in the course of normal plant metabolism. The concentration of radiocarbon in the individual organic compounds is approximately that maintained in the air of the chamber in which the plants are grown. By feeding animals radioactive forage or plant products their organic products are likewise randomly labelled and can be made available for tracer studies.

Whether plants or animals are grown with radiocarbon diets, it is

necessary to retain them in hermetically sealed chambers in which a number of factors, such as nutrition, temperature, oxygen and carbon dioxide supply, are under rigid control. In addition, various radiation-sensitive instruments must be utilized to monitor for possible contamination of the working area, thus insuring against radiation hazards.

The basic facilities necessary to the cultivation of radioactive plants and plant products, regardless of the particular isotope, stable or unstable, to be incorporated are shown in Figure 1. In comparable but modified chambers, animals can be maintained on radioactive diets for prolonged growth periods.

The plant growth-chamber experiments are yielding data on the fundamental growth requirements of higher plants. This is the result of being able to culture reasonably large populations of intact, normal plants in a system in which the various environmental factors are controllable. In addition the levels of radiation which result in significant toxicity can be easily secured. Likewise, it now will be possible to conduct critical surveys for plant products which have been undetectable with ordinary chemical methods. This is true for those compounds which are biologically effective at concentrations that are out of reach of the chemist. Most frequently we find this type of compound to be among the most important biological ones, such as, hormones and vitamins.

The biosynthesis possibilities in the case of animals are equally as great as those for plants. In either case, it is not necessary to produce large quantities of a given substance. For example, radioactive alfalfa that has recently been produced in the growth-chamber could be diluted 1000 times with ordinary alfalfa when used as the sole source of food for tracer, carbon studies with guinea pig.

The data presented give but a small insight into the applications possible with Atomic Energy. With respect to tracers, one can certainly be optimistic in evaluating the service that will be utimately rendered the field of biology by the many isotopes now being made available by the Atomic Energy Commission's Isotopes Division at Oak Ridge, Tennessee.

OUR BIG UNIVERSITIES

The 10 institutions with the largest enrolments reported are: New York University, 47,936; University of California, 43,426; The City College of New York, 30,192; Columbia University, 29,153; University of Minnesota, 25,084; University of Illinois, 25,062; Northwestern University, 22,822; Ohio State University, 22,416; Indiana University, 21,826; and the University of Wisconsin, 20,796.

Frank E. Goodell
1867–1946

Mr. Frank E. Goodell, the 20th president of the Central Association of Science and Mathematics Teachers, died at his home in Des Moines on Thursday, September 5, 1946, after several years of illness. Mr. Goodell was born at Morrison, Illinois, on February 20, 1867. Later the family moved to Emerson, Iowa, where he completed his high school education. At the age of twenty-two he received the bachelor's degree from the University of South Dakota and later did graduate work at Johns Hopkins University and The University of Chicago. His entire teaching career was spent in Des Moines with the exception of three years at the University High School at Iowa City. As a teacher he was unexcelled in presenting the subject matter of physics and chemistry in a way that challenged the minds of his pupils.

Mr. Goodell not only found time to teach but was a leader of teachers in the science organizations of the state and nation. He helped to found and served as president of the city science teachers of Des Moines; he was president of the Iowa Association of Science Teachers, and a member of the Iowa Academy of Science and of the American Association for the Advancement of Science. As a member of the Central Association of Science and Mathematics Teachers he will be remembered by our older members for his work in the physics and chemistry sections and for his excellent leadership in the Association, twice as vice-president in 1913 and 1925, and as president in 1926.

Mr. Goodell's excellent service to the cause of science placed his name high in the list of great science teachers, and his service in the important work of the churches of Des Moines made him a great local leader.

Dean C. Strand
Herbert H. Smith
Glen W. Warner

X-RAY-EYED MICROSCOPE GROWS MORE POWERFUL

The microscope with the X-ray eyes for peering into specimens of living tissue is growing more powerful. A new instrument with a magnification of 50 to 100 diameters, instead of the 10 reached by an earlier model, was announced by Dr. Paul H. Kirkpatrick of Stanford University at the meeting here of the American Physical Society.

The microscope, Dr. Kirkpatrick said, has a resolving power comparable to that of many microscopes operated with ordinary light. This resolving power, which is the ability of an optical instrument to give a distinct image, is more important than magnification.

THE ATOM AND THE ELEMENTARY SCHOOL

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Is it possible for elementary school children to understand atomic energy? Can we satisfy their interests relative to it? Is the concept beyond them?

These are some of the questions in the minds of educators today who are concerned with developing the school curriculum to keep pace with the ever changing needs and trends of society. The gap between theory and practice is wide, yes even between knowledge and practice.

Modern society demands a well rounded individual. Modern philosophy of education suggests that we live in a democracy that is still being built and one in which our young people must be ready to take part. In the building of this democracy are many problems. We are faced with the responsibility of guiding the complete development of each individual. Society is demanding a well rounded citizen who can assume both group and individual responsibility in community living, comparable to his ability.

This is a process of growth starting at an early age when the child is helped to feel that he is an important family member. This growth should continue in our schools with such experiences as are conducive to the development of respect for the rights of others, critical thinking, respect for minority as well as majority, cooperative planning, and sharing, and economic use of resources.

One of the major blocks to progress is our adult world. We are expecting children to solve adult problems at an adult level. If, however, we are putting into practice our philosophic trends, we shall tend to develop efficient community citizens.

In view of these trends, what are the implications of atomic energy for the elementary school child? Are we assuming our responsibility by doing nothing about it? No.

Many concepts of atomic energy have been ventured during the past few years. Children of a wide chronological range have some idea of it. Among these concepts, and perhaps outstanding, is the destructive force of atomic energy.

It was decided to work with a sixth grade group and attempt to determine through a unit on atomic energy how many and what concepts they could handle, with the idea of follow up in mind for grades above and below.

The school group which participated in this unit of work consisted of thirty-one children of average age range, social development, and mental achievement and ability—according to standardized norms.

The group was as nearly evenly divided as possible between the sexes and they shared the interests which characterize the normal ten to twelve year old child.

A keen interest in science as a preferred study was apparent in just a few individuals. Interest in the atom bomb, however, was very evident in a large majority of the group. In fact, the need for the study of atomic power and its present and future implications manifested itself in the strong, continual interests expressed by the children throughout the year. Questions, informal conversations, discussions, and oral reports concerning news articles, illustrations, and motion pictures were the means through which the children repeatedly evinced their interest in the "bomb" and its mysteries.

Since very little reading material—at the child's level—was available, it was apparent that the necessary information must be supplied through other sources and means. Thus it was, after a survey of the qualified personnel and available materials necessary to present the desired concepts, that the following unit of work was planned and presented.

The teaching unit on atomic energy consisted of six parts, each given separately on a different day, scattered over a period of three weeks. The several parts are explained in some detail below and were given to the class in the order in which they follow here.

Part I. Elements and compounds. We tried in this session to get across the idea that the universe as we know it is made up of 92 building blocks, which we call elements and from which a very large number of mixtures and compounds can be made or do occur in nature. Examples used to get across this concept were: the several building materials such as wood, steel, concrete, glass, etc. from which numerous buildings such as the school, church, store, firehouse, and their own homes are made; and the twenty-six letters of the alphabet from which thousands of words are constructed. The idea of several different compounds composed of the same few elements was also put across with these illustrations. Several samples of chemical elements and compounds were shown and the following experiment was actually done. Some chopped up red and green crayons were mixed (by shaking) in a test tube to show simple mixtures. They were then heated together over a candle flame until they were melted, whereupon they lost their individual color and illustrated the formation of a compound.

Part II. Atoms. The concept of atoms as the smallest parts of elements was given. A discussion of their minute size ensued and the children took small blocks of clay and a razor blade and attempted to cut down to the very smallest pieces. To illustrate further the small sizes of atoms in their role as components of elements, the idea of

discontinuity of printing inks as seen under magnification was used. To the unaided eye, the color seems continuous, but upon examination with a lens, it is shown to be made up of many very small individual specks of color. A comparison in size of an ant to a man and an atom to an ant was given.

Part III. Atomic structure. Here, the modern concept of the atom as a minute solar system was presented. A discussion of our actual solar system and its planets and their orbits was held and a comparison made to the structure of the atom. The pictures in color from *Life Magazine* were used to show atomic structure. The hydrogen atom structure was illustrated by using a small wooden ball at the end of a string, revolving around the fist as it was swung in circles. The fist represented the nucleus, the ball the electron in motion in its orbit. This structure was further shown by the illustration of a golf ball as a nucleus at the center of a football stadium and a mosquito flying at high speed around the edge of the field as the electron. Electrons, neutrons, and protons were presented as the building blocks of all elements. As in building words by using different combinations of letters, the atom is made up by using different combinations of these three particles. It was explained that the three particles are located in definite areas in the atom and that the number of electrons is always equal to the number of protons. It was pointed out that the number of each varies from one element to another.

Part IV. Radioactivity. In this session, the idea that some elements undergo a natural change through decay was presented. The reason used to explain the decay was the presence in the nuclei of some elements (radium and uranium were used as examples) of too many neutrons. This excess causes a strain or stress in the nucleus which finally results in a small piece being ejected with force, leaving thereby the remains of the original nucleus as a big piece, but different from its constitution before the decay. The particles ejected were called particles or little bullets and it was also explained that invisible rays of light, similar to some extent to X-rays are also given off during the decay. The relative speeds of airplanes and light rays and these particles were compared. The beneficial uses of these particles and rays in medicine were discussed. It must be said here that the response from the class to questions throughout these sessions and the contributions of pieces of information to the discussion were amazing to us.

Part V. Fission and chain reaction. The concept brought in here was that of artificially splitting the uranium atom with neutrons, as bullets, thereby setting off a controlled or uncontrolled chain reaction. (No discussion of the isotopes, U 235 and U 238 was included, the element's name only being used.) Comparisons used for putting

across the concept of chain reaction were the chain letter idea, and the geometric progression in a salary which begins as one cent the first day and doubles each day thereafter. The idea was put across that the uranium nucleus gives off two or more other neutrons when it fissions, thereby causing more fissions under proper conditions and results in a chain reaction. Two examples of chain reactions were used. One was a board on which matches had been so placed and glued that when one was lighted, it burned and set fire to two other matches and when they burned they set off two others each, making a total of four, and these in turn set off eight, and these sixteen. A wire cage containing twenty-four set mousetraps, each with one or two corks or rubber stoppers lying across its spring-killing wire was the second device used. When an extra stopper representing a neutron was tossed in among the traps, it set off one trap which threw its stoppers around the cage, hitting other traps which in turn did likewise, resulting therefore in a rapid and exciting chain reaction. It was explained during the session that these bullets and rays from radioactive materials as they decay are beneficial, but also deadly. It was pointed out that they are not preceived by any of man's senses, but can be shown to be present by the use of special instruments. One such device, a simple spinthariscope, was demonstrated to the class.

Part VI. Peace-time uses of atomic energy. The fallacy of waging an atomic war was briefly brought in, but the wonderful peace time future for atomic energy was emphasized. It was pointed out that industrial power was a possibility and that medical uses were already numerous. The pupils mentioned several magazine articles they had come across dealing with future uses of this power.

Part VII. Evaluation. The testing phases of evaluation of this unit took the form of a fifteen item objective-type test. The items were carefully selected in such manner as to measure the fundamental facts necessary for an understanding of the major concepts which were developed. Two of these major concepts lent themselves to some degree of measurement through direct questions which were included as completion type items in the test. The results of this test (sample copies and item analyses of which are available from the authors) showed that out of a possible total score of 21, the class mean was 16. The mean for the girls was 16.6 and for the boys, 15.4.

In an attempt to evaluate appreciations and attitudes derived from the understandings gained, each child was also asked to express his reaction to the complete study in colored illustration. The results of this form of evaluation proved very gratifying in that a sizeable percentage depicted very constructive peacetime usages of atomic energy. The remainder expressed in their illustrations a very definite

understanding of the facts upon which the appreciations depend.

The results of both forms of measurement (test and illustration) for each individual appear to show a remarkable degree of correlation in terms of factual knowledge gained and, in many instances, an application of that knowledge in the form of verbal or illustrated understandings.

Throughout the unit, the emphasis was upon simplicity of terminology, equipment, illustrations, and comparisons. In order that we might better remember for future evaluation and guidance the responses and questions during the teaching of the unit, tape recordings were made of each part. These have been received so favorably by groups to whom they have been played, that disk recordings of these tapes are now being made and will be available from the authors for classroom use by other teachers.

OUR ANNIVERSARY BOOK AGAIN

The work of writing has progressed to a stage where editorial changes and revisions can be made, and by the time the March issue of SCHOOL SCIENCE AND MATHEMATICS reaches you the manuscript will no doubt be in the hands of the printer. Our editor-in-chief, Mr. Walter H. Carnahan, reported at the Chicago convention that "it is a job well done." You will no doubt be interested to know a little more about

A HALF CENTURY OF TEACHING SCIENCE AND MATHEMATICS

In the table of contents we have a fine perspective view of the range of subject matter which is presented.

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3. A Half Century of Teaching Biological Sciences by

   Jerome C. Isenbarger
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4. A Half Century of Teaching the Physical Sciences by

   Ira C. Davis

Allen F. Meyer
Milton O. Pella

5. A Half Century of Training Science and Mathematics Teachers by

G. P. Cahoon
J. S. Richardson

The 200-page book will give you a concise picture of one of the world's most revolutionary half centuries in science knowledge and teaching procedure. Also, never before has the world so fully recognized the absolute necessity of co-operation between the sciences and mathematics.

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J. E. Potzger, *Chairman*
Promotion Committee

CONFERENCE ON SECONDARY SCHOOL EARTH SCIENCE EDUCATION TO BE HELD IN BOSTON, MARCH 17–18

A conference on the Teaching of the Earth Sciences in the Secondary Schools will be held at Boston University on Friday and Saturday, March 17 and 18, 1950. It will be open to all interested persons. Dr. C. W. Wolfe, chairman of the geology department at Boston University, is Chairman of the Conference, which is being sponsored by the Earth Science Institute, a non-profit organization created exclusively for education in and promotion of the earth sciences.

Among the topics to be discussed at the Conference are: a survey of earth science education in the secondary schools; the scope of curriculum at secondary school level; necessary teaching aids and laboratory equipment; and the preparation of teachers. Discussion periods will follow each talk. A field trip will be held on March 18 to Squantum, Massachusetts. The Annual Meeting of the Earth Science Institute will be held on the evening of March 17.

Drs. Chester R. Longwell, C. S. Hurlbut, Jr., David Delo, and C. W. Wolfe are among the speakers scheduled to talk at the Conference. The final program will be released on February 15. Suggestions as to the program and to the content of the Conference should be addressed to Dr. C. W. Wolfe, Geology Dept., Boston University, 725 Commonwealth Avenue, Boston 15, Mass.

A number of educational institutions and publishing houses will hold exhibits at the Conference. There will be no charge for exhibit space, the closing date for which will be March 1, 1950.

Complete information and material on the Conference will be sent to those persons addressing requests to the Executive Secretary, The Earth Science Institute, Revere, Massachusetts.

Jerome M. Eisenberg
Executive Secretary
The Earth Science Institute

SOME DEVELOPMENTS IN SCIENCE TEACHING AND TESTING*

Philip G. Johnson
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Coming before members of the Central Association of Science and Mathematics Teachers and talking about developments in science teaching and testing is like trying to tell members of a Lion's Club a new story or even new wrinkles on a familiar story. You will be familiar with many of the developments which I purpose to mention in this discussion but it is my hope that there will be some phases to the developments which might suggest to you some materials and procedures which you will judge to be worthy of actual trial. It is through trials and revisions that we will be able to assay the real values of these developments.

One rather significant fact about the title to this discussion is the evident relationship of teaching and testing. Too many science teachers act as though teaching is one thing and testing is quite another thing. They do not use tests as the great aids to learning which they truly can be and they do not give adequate consideration to the developing of tests for several of the important goals which they profess to be their teaching goals. For example, we can find teachers who give much time and thought to marking papers; writing in words, phrases, numbers and explanations, then handing the papers back to the pupils. Most of the pupils give little attention to the remarks other than the grade. How much better it is from the viewpoint of teaching and learning if the teacher leaves the papers unmarked except for a grade and thereby puts the pupils in the mood to ask "What did I do wrong?" I realize that the teacher would have to keep a summary sheet showing the performance of each pupil on each test item but that is a simpler task than marking all the papers and it also provides a record which can be used as a setting for some needed teaching. It can also serve as information useful for improving the tests given by the teacher. We might also consider the teacher who gives much time and thought to the arranging of experimental demonstrations, laboratory work, models and other visual aids, and interesting questions. They believe that such materials and the associated procedures cause changes in the pupils. Nevertheless, in the testing they limit themselves largely to the narrow area of growth in knowledge. They should plan to test for changes in ability to observe accurately and describe honestly, changes in attitude and interest, changes in bases for values, changes in abilities to sense and

* Read before the Senior High School Group of the Central Association of Science and Mathematics Teachers Chicago, Nov. 26, 1949.

deal with problems, and the like. As teachers attempt to develop courses and procedures that change the emphasis on outcomes it is important that they attempt to develop and use tests that may provide evidences indicating progress in the new directions. Good teaching and good testing should go hand in hand.

Some Over-all Developments Influence Teaching and Testing:

Several things have happened and are now happening to secondary education which influence our teaching and testing. One of these is the growth of our secondary school enrollments until we now have in our high schools the great majority of the youth of the age group that is usually associated with this level of education. There have also been some changes in our thinking concerning the growth and development of secondary school youth leading to the idea that schools should attempt to educate the whole youth rather than making a number of piecemeal contributions to such development. We have also seen and we are now experiencing a shift in relationship between general and specialized education. We can note a growing relationship between general and vocational education in what has been called Life Adjustment Education. We sense the upward trend of general education reaching into the junior college levels. To these changes might be added the very tremendous developments in scientific and technical knowledge. All of these changes have truly great implications for our teaching and our testing.

There Has Been a Great Increase in General Courses:

The growth of our high school enrollments, bringing in as it does a large number of students who have no specialized interests, has placed before the teachers and administrators the need for adapting courses and procedures to recognize general needs and interests. Coupled with this development of general education has been a growth in public appreciation and concern for science. We as science teachers have thus been swept into the developing of courses and procedures that might make science an integral part of the general education program. The resulting changes have included an expansion of science at elementary school levels, general science and health science at junior high school levels, science within core courses, general biology at the lower senior high school levels, and various attempts to generalize the physical sciences at the upper senior high school levels. There has also been a great development of science for general education at the junior college levels.

In the course of these developments toward generalized science courses at all levels of instruction much of what science teachers have considered valuable has been minimized or dropped while other

aspects have been given new or increased emphasis. These changes have been made in attempts to recognize the needs and interests of nearly all the youth now in our high schools. Thus there has been a shift from the mastery of a large number of scientific facts toward fewer but more generally significant facts. Principles which formerly were discussed largely in terms of what they meant in various forms of scientific work are now related to the life activities common to a majority of people. Laboratory work which emphasized scientific information and processes has been changed to include consumer types of operations and uses, and in many cases such experiences have been reduced, if not eliminated, except for what might be done within a single class period.

The generalization of the sciences at high school levels is especially vivid in the area of the biological sciences. The more specific information which was a part of separate botany and zoology courses has now been modified so as to fit into a general biology course. This change is rather common even at the junior college levels. It is true that many science teachers have resisted this change and even now they make one semester of their biology course botany and the other semester zoology. Nevertheless, a large number of biology teachers have generalized their courses through the placing of stress on the understanding of biological principles which apply to animals, plants and humans. While the generalization of science courses and procedures has shown great strides at the lower senior high school levels on the one hand and at the junior college levels on the other hand, the upper senior high school science teachers have resisted this trend and many high schools continue to have rather specialized physics and chemistry courses as the only science offerings which are planned for eleventh and twelfth grade pupils. A growing number of high schools are moving toward the generalizing of the physics and chemistry courses with the expectation that an increased number of juniors and seniors will study them with interest and value.

There Has Been a Growth of Parallel Courses:

The interest in providing science instruction for an increasing number of general students has brought about the development of parallel science courses such as Biology A and B or General Biology and Biology, with similar courses related to physics and chemistry. Some schools have established a physical science course to parallel the physics and chemistry courses. The "A" course has often been the "Academic" course with its stress on specific facts, specialized technics, and quantitative relationships while the "B" course has been the "Broad" course with reduced emphasis on laboratory work, quantitative relationships, and specific facts, and with increased em-

phasis on the applied and consumer aspects of the science. Visual aids have often been more freely used in the "B" courses than in the "A" courses. Since the same teacher has often taught both types of courses in the same rooms, the real difference has perhaps been in the standards of attainment expected of the pupils rather than in the organization and instructional procedures. Many science teachers may not have said so, but in their thinking and acting the "A" courses were academically respectable while the "B" courses were bogus. Many science teachers have, however, accepted the fact that there are a very large number of general students in the high schools at all grade levels and they have made sincere and thoughtful attempts to meet the needs and interest of such students. As a result they have found new ways to enrich the educational media not only for these general students but also for their students with specialized and scientific interests. Many teachers have found it desirable and possible to do this within their existing courses without the establishing of parallel courses.

Many Courses Have Been Reorganized to Meet New Needs:

While some schools have seen fit to develop new courses including parallel courses an even larger number of schools have found their science teachers willing to revise their courses and procedures so as to focus increased attention on individual and societal needs. In the revision of courses this has usually meant the regrouping of the science content into larger blocks, enriching the blocks with many and varied examples of everyday and non-specialized uses for the principles and information, and minimizing or omitting some of the aspects of the courses which have become obsolete or relatively low in direct practical utility. The Committee on Correlation of High School with College Chemistry of the Division of Chemical Education pointed this direction for chemistry in 1936 when they published a recommended course in eleven units. Their units were strictly content areas associated with chemistry but other science teachers have reorganized their science courses into large blocks on such different bases as community resources and opportunities, current science problems, pupil interests, or some combination of these with other bases. This organizational framework has been adopted in some colleges under the "blocks and gaps" plan and when implemented with changes in instructional procedures there has resulted what many leaders consider to be a successful adaptation of science instruction for general students. The need for tests to help confirm such opinions is urgent.

The importance of changes in instructional procedures should not be minimized. Many science teachers have without a change in organi-

zational framework made useful adjustments to the needs of general students through plans for recognizing individual needs and interests by the use of individualized and socialized procedures. Teachers whose major work is at the lower high school levels, where a high concentration of general students is to be found, have felt keenly the need for changes in instructional procedures. They have found differentiated assignments and optional work helpful in adjusting their instruction to the wide differences in abilities, interests, and rates of learning. Even in schools that practice ability grouping there are such wide differences in interests and rates of learning that differentiated assignments and optional work have been very helpful. Let us consider briefly the nature of some of these changes in instructional procedures.

There Has Been a Growth in Individualized and Socialized Procedures:

The general and the specialized interests and needs of high school youth can be well served in the majority of high schools through the reorganization of courses coupled with the use of individualized and socialized procedures. In such procedures science teachers reduce their amounts of formal instruction through the use of learning guides which pupils can follow with but little help from the teacher. The teacher is then free to help the pupils who find learning difficult and to stimulate other students to undertake special projects which are suited to their abilities. Some teachers have found it helpful to arrange learning guides for three levels of ability and interest. In addition to learning experiences required of all pupils in a group, each of the learning guides will contain many and varied suggestions for optional work and projects. Some science teachers have arranged learning guides for use with committees or groups of students where the varied interests and abilities among four to eight pupils are brought to bear on an area of subject matter, a resource, a problem or some other division of a unit. Similar learning guides are arranged for other groups who will attack other phases of a common problem or unit. One science teacher who became sensitive to the numerous ways in which common legal procedures affect people decided to pattern some of his science teaching on the legal procedures which all persons should know and to indicate how civil and natural laws were different. One science teacher, who had noted how the community chest campaign was organized and carried through, decided to use this as a pattern for arranging teams of pupils in a class and thus carry through the scientific and social learning which he considered of value for general education. Some science teachers have taken the older contract and unit plans and have adapted them for use in their science classes. Some science teachers have made no major changes in

their plans of teaching but they have increased their use of auditory and visual aids and some have made a major change in their laboratory work, for example the adoption of semi-micro methods.

Since individualized and socialized procedures put the stress on different kinds, amounts, and rates of learning, it becomes necessary to recognize such differences in the tests. If no changes are made in the tests to adjust them to the changes in goals, it is obvious that the modified plans or procedures are likely to come out a poor second when compared to the traditional courses and procedures for which the tests were designed. Science teaching and science testing must be related to each other and to the goals of instruction.

New Scientific and Technical Knowledge Call for New Teaching and Testing:

When we survey the new information and processes which have become realities in the last decade, we realize that science teaching and testing at all levels must develop some new patterns. Some high schools now have oscilloscopes, Geiger counters, atomic models, specimens in clear plastics, samples of antibiotics, models of jet propelled rockets, television receivers, and the like. One State has a Geiger counter and specimens in plastic available for loan to schools. The surplus property program aided many schools to get specialized equipment. Scientific supply companies have manufactured new demonstration devices to meet the need for teaching about some of the new developments. Industrial companies are distributing booklets, charts and samples to reveal new developments. Some science teachers are getting and using radioactive tracers.

Teachers here and there have individually worked out ways to use these new materials in order to help youth understand new concepts and processes. Efforts have been made to evaluate the present educational status of pupils and adults concerning these developments and to note changes, if any, growing out of planned experiences relating to them. There is a need for reports bringing together the findings concerning how new devices can be used effectively. There is also a need for information about tests and other evaluation instruments which will show what happens to pupils in schools where current materials and processes are given consideration.

Teachers are Testing for Changes in Interest and Experience:

A teacher who sincerely wishes to adapt instruction to differences in interests, abilities, and needs, will attempt to use and perfect interests and experience inventories. In one form such an inventory would involve giving the pupils a rating sheet on which they could indicate their degrees of interest and experience. Scales using steps

such as the following have been used.

A. ( ) What I have done a lot.
( ) What I have tried a little.
( ) What I have not tried but would like to try.
( ) What I have not tried and do not care to try.
( ) What I would detest doing.

B. ( ) Greatly interested in
( ) Somewhat interested in
( ) Indifferent to
( ) Dislike somewhat
( ) Dislike very much

C. ( ) Believe strongly
( ) Believe but interested in more evidence
( ) Believe but uncertain about
( ) Believe weakly
( ) Do not believe at all

The first two of these scales should be related to a number of different kinds and amounts of doing, such as: thinking, making, modeling, collecting, photographing, identifying, reading about, drawing, looking at, experimenting with, using, watching, visiting, finding out about, taking apart, putting together, studying, talking about, writing about, understanding, going to, and the like. These activities can be related to a number of specific things which are or can be associated with the course. While no single response may mean very much, the sum total of the way a pupil reacts to various types of activities in a rather long and intermingled list will give some indication of where a pupil is at a certain stage in the course. It is obvious that the teacher must develop subtle methods for introducing and using such inventories in order to get honest and frank reports from the pupils. The use of the same or of a comparable inventory later may provide some evidence of change.

Science teaching is concerned with beliefs and bases for beliefs. A science teacher who is interested in this aspect of possible pupil growth may wish to try to use a belief inventory which can be related to a number of superstitions, deliberate lies, hunches, horoscopic and other types of fortune telling, guesses, hypotheses, ideas built on circumstantial evidence, experimental outcomes with and without controls, theories, principles, and laws. Again any single response may be of little significance but the summary based on reactions to a long list may tend to indicate the pattern of the pupils' beliefs, their sense of values, and their bases for truth. Repeated use of such a scale or a comparable one may give some evidence of changes resulting from science teaching.

Self-Checking Examinations and Evaluation Forms are Helpful:

One evidence of good teaching is the amount of responsibility which each pupil assumes for his own progress. This can be en-

couraged by setting the stage for a pupil evaluating his own work as well as in having pupils share in the evaluation of the work of others. This can be applied to simple written reviews, assigned papers, notebooks, and comprehensive examination. Let us look at how this may be encouraged in the tedious task of looking over notebooks. If the teacher has discussed and stressed certain standards for notebook work the encouragement of self evaluation is rather simple. It can be implemented by a rating sheet on which each factor related to a standard is mentioned and where there is a place to indicate how well this standard has been met. If there can be spaces provided for three separate ratings then the first can be done by the pupil himself, after an opportunity for improvement the second rating can be done by another pupil in the class, and after another opportunity for improvement the third rating can be done by the teacher. No teacher need feel that it is necessary to rate all the notebooks each time they are called in. An inspection of the pupil ratings and a careful rerating now and then can be sufficient. The same type of pupil-teacher rating scale can be applied to successive units in the course and the idea can be established that the pupil can constantly grade himself and judge where his work must place in comparison with the standards.

During the learning phases of a unit a teacher can distribute a comprehensive examination covering one or more aspects of the important learning goals. The pupils can be encouraged to check their progress from time to time by working on items of this test. As the end of the unit is approached the taking of the test can be assigned part by part over several days. Each day some time can be given to a discussion of the parts of the test assigned and the correct answer can be made definite for all the pupils. The pupils can be encouraged to practice this correct response by distributing a practice sheet and taking time to show them how they can take the test, check their own results, restudy the correct response, take the test again, and to continue such testing and relearning until they approach a perfect score. When the final test, which is comparable to this practice test, is given the pupils will be more certain of their knowledge and they will indicate that they have achieved a great deal in the study of the unit.

Some teachers are lukewarm toward such self-checking procedures because they feel too much emphasis is placed on memorizing specific facts. It can be said that pupils should certainly fix a number of specific facts during the study of a unit; therefore a scheme which helps them to fix the desired facts is helpful. It can also be said that mere memorizing can be reduced through the making of very comprehensive tests with a large number of test items, many of which require the pupils to recall principles, and through thinking only can

they determine the answers in the varied situations which the test stresses. It is also possible to devise various types of tests such as those involving problem situations, tests of relationships, evaluation of data, selection of evidence, cause and effect relationships, and the like. True-false, multiple response, completion, matching, and short answer forms lend themselves to comprehensiveness and can be used readily in self-checking tests. Some of the other types are more difficult to grade but they have great value as aids to learning and through experiences with them teachers can see more and more significant ways to use them for purposes of teaching and evaluation of results.

Differentiated Instruction Requires Differentiated Tests:

When science teachers arrange learning guides for different levels of ability and interest, it becomes necessary to plan tests to recognize the differences emphasized in the learning guides. Some teachers do this by preparing one very comprehensive examination and expecting pupils to show different degrees of achievement on this test. Many teachers do not consider this flexible enough and therefore, they develop two or three forms of a test for each level or group around which learning guides are prepared. Since there are several interchangeable forms the pupils are less interested in studying up on any one form. The great need for several forms results from the opportunities for different rates of progress which causes pupils to become ready for a test at different times. There is also a need for tests which can be scored quickly in order that pupil progress can be reported and the pupils instructed either to proceed to the next learning guide or to give further study to their present learning guide or an alternate study guide.

Answer Sheets Simplify the Problems of Grading:

Since a good examination must be comprehensive through the inclusion of many tests items the problem of grading can become very tedious unless plans are carefully made for grading when the test itself is constructed. It is possible to arrange answer sheets which are easy for pupils to use and simple to grade. The forms 1, 2, and 3 have been found helpful for the various common forms of objective examinations.

The true-false and the multiple response types of answer sheets can be scored by taking a correctly marked copy and punching out the correct spaces. This punched copy when placed over a pupil's copy makes it easy to count the number of correct responses. Pupils can help in this scoring process. The matching and completion form can

Form 1. TRUE-FALSE:

Test Item	T	F	?
1			
2			
3			
4			
5			

Pupils show their knowledge by marking in the "T" column if the statement is true, the "F" column if false, and the "?" column if they do not know. More than 100 test items can be coded on a single sheet by this plan.

Form 2. MULTIPLE RESPONSE:

Test Item	A	B	C	D	E
1					
2					
3					
4					

Pupils can show their knowledge by marking one or more spaces or to show their order of choice by numbering the responses. More than 100 responses can be coded on one sheet.

Form 3. MATCHING or COMPLETION:

Test Item	Related Item
1	
2	
3	
4	

Pupils can show their knowledge of the related item by either inserting the number of the related idea or inserting the proper word, number, or phrase in the blank. More than 100 such responses can be coded on a single page.

be scored by using strips with the correct responses shown at the places corresponding to the spaces on the answer sheet.

The teacher can avoid marking the pupil's copy more than to put down the total score thus leaving the pupil to wonder where mistakes were made. The teacher can keep a master copy showing the various responses of pupils on each test item thus providing a basis for discussion of items that were frequently missed and for the revision of the test to include better test items. Then too, the test copies can be collected and used more than once.

Most teachers will not be satisfied to give only objective test items in an examination. For other types of responses the back of the

answer sheet can be used thus causing pupils to turn over the sheet when finished and thereby reducing the temptation and possibility of copying.

Teachers who have available an electrical scoring machine can obtain prepared answer forms and cannot only get their papers scored rapidly but they can also get an item count showing the total responses of the pupils on each test item. Such tabulations provide excellent bases for reteaching as well as for test improvements.

Tests Can Be Improved by Keeping Performance Data for Each Test Item:

If teachers believe that a test is no better than the test items of which it is composed they will be interested in studying the results on each test item, recording such performance data each time the item is used, and considering the data in the development of new tests. One plan for working on the improvement of test items is to develop and use an organized file of test items. After each use of a test item the performance of a group of students can be coded on the card. The data can show how well a class of students performed on the test item but it may also be desirable to show how effectively the test item worked with students at different levels of achievement.

One plan for determining performance patterns is to group all the papers related to a test into quartiles based on total scores. Each quartile of papers is then given an item count and the success of each quartile on each test item is shown in per cent. It is also possible to show the degree of difficulty of the item and the discriminatory value. The following coded data represents a number of separate test items.

1.	6/9/41	(283)	94	86	82	74	11/74/55
2.	6/9/41	(283)	66	59	35	13	78/12/9
3.	6/9/41	(283)	100	99	94	90	2/85/75
4.	6/9/41	(283)	94	73	55	16	52/ 2/1
5.	6/9/41	(283)	99	97	87	59	19/74/73
6.	6/9/41	(283)	66	24	21	24	85/30/64
7.	6/9/41	(283)	34	16	1	0	109/84/87
8.	6/9/41	(283)	55	59	66	63	50/90/90
9.	6/9/41	(283)	100	80	52	14	60/ 1/1
10.	6/9/41	(283)	33	30	31	28	115/89/89

In this listing the first number is the number of the test item, each one being a different test item. The second series indicates the date of the test and the number in parentheses indicates the number of pupils who took the test. The next series indicate the percentage of pupils in each quartile who marked the item correctly. The first of the last three numbers indicates the general difficulty of the item when all items are considered, the second number shows the position of the item on the basis of overall spread between the upper and the

lower quartile, and the last number shows the overall location of the test item in a factor representing overall discriminatory value. If such data were recorded for each test item over several times that the item is used there would be several series of data and it is interesting to conjecture how the test item would perform when used in different years with different classes. Some evidence shows that the performance pattern is reasonably constant for successive classes and that the data is therefore an important characteristic of the utility and effectiveness of the item. Additional research concerning this problem should be undertaken.

A conservative appraisal of data concerning performance of classes on various test items would indicate that such data can be of great help in not only selecting test items for various purposes but also in helping teachers learn how to prepare better test items. Through some such procedures we as science teachers can become more and more effective in both teaching and testing.

Rating Scales Related to Instructional Factors:

Each and every test given by a teacher should be, in part, a test of his own effectiveness. The performance of students is in part due to the nature of teaching, in part due to the nature of the learning, and in part due to the nature of the testing. Each of these parts should be considered in evaluating the work of the pupils.

The concern of teachers for getting across certain subject matter and for stimulating learning causes some of them to overlook themselves as factors in the learning process. In order to face this factor squarely some teachers have made use of rating scales related to instructional factors which are more or less personal. The rating scale may have steps about as follows:

( ) Excellent
( ) Very Good
( ) Satisfactory
( ) Not so good
( ) Poor

This scale can then be used with such instructional factors as: general usefulness of content covered, helpfulness of demonstrations performed, how useful the discussions were, the extent of the teacher's sense of humor, the helpfulness of the films used, the nature of the home assignments, the length of the home assignments, the value of the notebook work, the fairness of the tests and examinations, and a number of related and more specific factors. A study of the results from such tests can help a teacher avoid deep personal and professional ruts or to determine the consistency with which a teacher maintains a rut. Proper care must be exercised in guarding the identity of

the pupils so that frank and sincere responses will be made. The use of rating scales of this type from time to time during the year and near the close of school when all grades are in, can be exceedingly helpful to a teacher. Here is a clear case of where a teacher is willing to practice self-evaluation. This type of evaluation has been extended in some schools to include many factors which go beyond the classroom activities.

Summary

It can be stated that the secondary school population has changed and that teachers of secondary school pupils have changed many of their ideas about how pupils at this age level grow and develop. There have also been major developments in scientific and technological accomplishments. In recognition of these developments teachers have established new courses and revised existing courses. They have also made many changes in instructional procedures and materials. Developments in the construction and use of instructional and achievement tests have been especially great.

It is the opportunity of all science and mathematics teachers to consider how to make the wisest use of these developments in order that our youth may grow in scientific enlightenment while coming to a clearer understanding of the role of science and the work of scientists in home, community, national and international affairs. Then too, teachers must consider how pupils with high abilities can move toward that place in our society where their talents will count for the most both to themselves and to others.

FAMED HORTICULTURIST WILL SPEND 92nd BIRTHDAY IN JUNGLES OF AFRICA

Liberty Hyde Bailey, the greatest authority on palm trees, garden plants and blackberry bushes in the world, will spend his 92nd birthday this month while on an expedition in the jungles of Africa. He plans to bring back with him rare specimens of palms to add to the collection of 150,000 plants in the Bailey Hortorium at Cornell University. "Hortorium" was a new word, manufactured by Dr. Bailey, which he felt more accurately described his collection than "herbarium."

Long and sometimes dangerous plant collecting trips are no novelty to the still vigorous horticulturist. He spent his 90th birthday alone on an island in the Caribbean, his 89th somewhere up the Amazon River in Brazil.

In addition to his travels all over this country, in South America, China and New Zealand, Dr. Bailey has found time to be the pioneer of modern agricultural educational methods, to edit 156 books about plants, to edit a magazine and to engage in plant breeding and experimentation. He accomplished all this because at an early age he planned his own life program: 25 years of study, 25 years of teaching, and 25 years to do whatever interested him most.

Now well into his fourth 25-year hitch Dr. Bailey is still enjoying himself, still traveling and still collecting plants.

GRAPHICAL METHODS IN SCIENCE AND MATHEMATICS TEACHING*

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The ability to construct and interpret graphs of various kinds has been an accepted objective of mathematical education for at least twenty-five years. One justification for this objective has been that graphs are used not only in mathematics but also in many other sciences. Modern courses in the junior high school grades, in general mathematics, and in algebra, treat the common types of statistical graph much more completely than was customary a quarter of a century ago. Improvements in the instruction on the graphical methods more useful in the exact sciences are much harder to find. These useful tools are still neglected, and far too often are treated superficially. This paper will discuss some of the notions frequently overlooked in teaching and using graphical methods. The intent is to encourage teachers of mathematics and science to use graphs more effectively.

Major Purposes of Graphs

In teaching, a few simple examples usually suffice to make clear three main types of activity in connection with the use of graphs.

(1) A graph may be read to determine at least approximately the value of an item of data.

(2) The relationship between two items of data may be observed from a graph; that is, simple non-precise comparisons are facilitated.

(3) More general relationships, or trends, among several items of data may sometimes be inferred by the aid of a graph.

Suppose we have two sets of data such that to each member x of one set there corresponds a definite member y of the other. For example, the first set may consist of a list of names of persons, and the second set may consist of the ages in years of these persons at some specified time. A convenient way of organizing these data is in the form of a table.

* A paper read by Maurice L. Hartung at the forty-ninth annual convention of The Central Association of Science and Mathematics Teachers on November 26, 1949, based in part upon an unpublished manuscript by Robert L. Erickson.

TABLE 1

Name	Age
Allen	15
Ben	7
Carl	12
Dan	12
.	.
.	.
.	.

Two types of behavior are now possible. First, the student can *read* the table; that is, tell the age of a particular person. Second, the student can make *comparisons;* for example, compare Allen's age with Ben's. If these data are to be exhibited in graphical form, a bar graph would serve best because of the nature of the independent variable—the set of names. Now the reading of data from a bar graph is usually a more difficult task than reading from a table, but rough comparisons are easier because of the visually observable relations among the lengths of the bars. Comparisons are made of lengths instead of the actual numbers they represent.

The recognition of general trends is probably the most important use of graphs. Suppose that, in addition to the age of each person in the set referred to above, the weight in pounds is also known. There is then a weight corresponding to each age, and the tables may be combined. For the purpose of reading the data, or of making relatively accurate comparisons, the table remains superior to a graph. If, however, the relationship of weight to age is to be studied, a graph has advantages. By making simple comparisons, the set of ages may be arranged in order of increasing magnitude, and then the use of a line graph on a two-coordinate system is appropriate. The "trend" of the line, if there is any, helps to indicate the nature of the relationship.

TABLE 2

Name	Age	Weight
Allen	15	127
Ben	7	60
Carl	12	90
Dan	12	95
.	.	.
.	.	.
.	.	.

All this may be obvious to the experienced teacher, but it is not so to the student. The latter is frequently unaware of the relative advantages and disadvantages of different methods of representing data. The student often thinks that the purpose of a graph is merely to "picture" the data. The great popularity of pictographs in newspapers, magazines, pamphlets, and books has helped to create this impression. Most pictographs are more difficult to read—that is, to find the actual numerical values shown—than a tabular arrangement of the same data. It is also true that a good bar-graph representation of the same data is easier both to read and to interpret. In seeking to exploit the main advantage of the pictograph—namely, its eye-appeal

or interest-attracting features—many graph makers reduce its effectiveness from the standpoint of ease of reading and of making precise comparisons. If well made, it does lend itself to the making of rough comparisons and the recognition of trends.

Graphical Scales

If graphical methods are to be made more effective, the student must learn not only the purposes of different forms of representation of data, but also certain principles which influence the interpretation. Even experienced teachers frequently state without qualification that the graph of $y=ax$ will be a straight line, and that the graph of $y=ax^2$ is a curve. Unfortunately, these statements are not necessarily true. The assumptions concerning the scales employed are of vital importance in making statements about graphical representations. Thus if a table of values derived from the relation $y=ax$ is plotted on a rectangular coordinate system in which the x-scale is uniform and the y-scale is a non-uniform scale of squares, the points will not lie on a straight line. If $y=x^2$ is plotted on a system in which the x-scale is uniform, but the y-scale is a non-uniform square root scale, the points for $x\geqq 0$ will lie on a straight line. (See Fig. 1.) By a proper

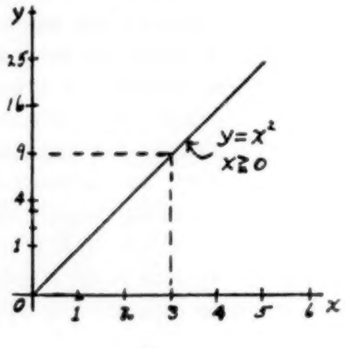

Fig. 1

adjustment of the y-scale, the graph of $y=ax$ for every value a will bisect the angle between the axes and have an inclination of 45°. Similarly, the graph of $x^2+y^2=9$ will not look like a circle, even if the scales are both uniform, unless the same unit length is used on both axes. Statements about the slope of a line or curve, or the appearance of a curve, are often ambiguous or false unless the scales used are assumed to be uniform and have the same unit length on both axes. In short, attention to the role of the scales and their varieties is one of the neglected aspects of instruction in graphical methods.

In general, the construction of a scale is based upon a formula of

the type $d=mf(x)$, which is called the equation of the scale. Let $f(x)$ represent an increasing (or decreasing) continuous function of a real variable x on some specified domain $a \leqq x \leqq b$, and let d represent a number of units of length (inches, centimeters, etc.) to be measured on a line from an arbitrarily chosen point. The number m, called the *scale modulus*, adjusts the range to the total length of the scale.

For example, to construct a square root scale, let $d=m\sqrt{x}$. Suppose $0 \leqq x \leqq 25$, and that the scale is to be 8 cm. long. Then $8=m\sqrt{25}$, and $m=1.6$. Hence $d=1.6\sqrt{x}$. This formula may be used to compute d for various values of x. These distances are measured from a chosen point on a straight line and are *labeled with the corresponding value of the variable.* The scale is non-uniform, since $f(x)$ is not a linear function. The y-scale in Fig. 1 is a similar scale with $m=1$. By assigning other values to x, additional subdivisions may be introduced. See Figure 2.

FIG. 2

This method of scale construction, which is explained in books on *Nomography*, may be used to construct scales for many of the elementary functions. Thus if $f(x)=\sin x$, where $0 \leqq x \leqq \pi/2$, a sine scale is produced. If $f(x)=\log x$, the result is the familiar logarithmic scale as found on semi-log or log log graph paper, or on the slide rule. The equation of the T scale on the slide rule is usually $d=m \log (10 \tan x)$ where $5.7° \leqq x \leqq 45°$, and $m=25$ cm. for a "10-inch rule." By making two such scales for $f(x)=x^2$, and gluing one of them on the slide and the other on the stock of a slide rule, the formula for the right triangle, $r^2=x^2+y^2$, is easily solved. Scales of this type have appeared on some commercial slide rules, but are not needed because the same result can be obtained with one setting of the slide on a good modern slide rule.

From this very brief review of the theory of scales it can be seen at once that the equations of the scales usually constructed in mathematics and science classes are of the type $d=mx$. Thus $f(x)$ is restricted to the simplest of types, and the resulting scales are uniform. Usually $m=1$, but if the main divisions on the graph paper are labeled 0, 2, 4, 6, . . . , it is equivalent to taking $m=\frac{1}{2}$; if they are labeled 0, 10, 20, . . . , it is equivalent to taking $m=1/10$. It would seem, for reasons that will appear in the next section, that experiences in the construction of scales based on functions somewhat more complicated than $f(x)=x$ would be valuable additions to algebra courses, and might well replace some of the time now spent on relatively useless techniques.

Adjacent Scales

A single graphical scale in isolation is not very useful, but two or more scales placed in a proper relation to each other become useful tools. One of the more familiar examples consists of a centigrade scale and a Fahrenheit scale drawn on opposite sides of the same line. If carefully drawn and from 10 to 20 inches in length, the conversion of temperatures from one unit to the other is easily accomplished by reading from one scale to the other. For this purpose the adjacent scales are superior to the use of a line graph of $C=5\ (F-32)/9$ on Cartesian coordinates. The mental processes and the eye movements needed to convert from C to F, or vice-versa, are much less complex with adjacent scales. On the other hand, the line graph, if well understood, is probably better for showing the nature of the functional relation.

Before considering other examples of adjacent scales, a review of the general theory may be advisable. Let $f(y)=F(x)$ represent an equation in two variables. Since the functions f and F must be reasonably well behaved, assume they are continuous and either increasing or decreasing in a specified range. Then take $d=mf(y)$ and $D=MF(x)$ as the equations of the scales. One of these equations may be used to determine the modulus. The same number should be used as the modulus in the other equation, so that $m=M$. Suppose, for example, that adjacent Centigrade-Fahrenheit scales about 20 cm. in length are to be drawn, with $0\leqq C\leqq 100$ and $32\leqq F\leqq 212$. Then $d=0.2C$ will produce a uniform centigrade scale, and $D=0.2\times 5\ (F-32)/9$, or $D=(F-32)/9$ will produce a uniform F scale. Subdivisions to the nearest Fahrenheit degree, and Centigrade half-degree, are feasible. Such scales, of varying length, are commonly observed on thermometers. In Figure 3 adjacent scales for the period of a simple pendulum, $t=2\pi\sqrt{L/g}$, are shown.

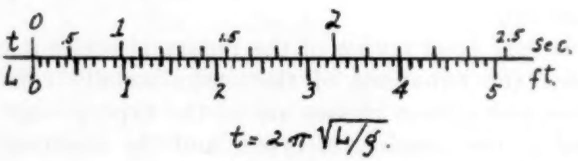

Fig. 3

For many simple formulas the scales are easily constructed without recourse to the scale equations. Thus scales for the relation $P=2Q$ between pint and quart measure can be drawn by labeling each division of a *pint* scale above the line with a number which is the double of the number on the corresponding division on a *quart* scale below the line. There is little to be gained from such a simple scale,

but if sub-divisions to tenths are introduced, the conversion of quarts to pints, or vice-versa, for values to the nearest tenth, is easy without any computation. It is also useful to observe that such scales show proportions in easily recognizable form.

Whenever conversion from one unit of measure to another is frequently needed, the possession of a set of adjacent scales is a great time-saver. Centimeters to inches, nautical miles to statute miles, miles per hour to feet per sec., and vice-versa, are examples. Some of the technical manuals used extensively during the war contained adjacent scales for conversions of this type.

When the functions to be scaled are not so simple, the scale equations are useful. The construction of adjacent scales for squares and square roots, cubes and cube roots, logarithms, and other non-linear relations can be made with the aid of a table for the functions, but consideration of the scale equation in connection with the work will add to the mathematical growth of the student.

By using two or more sets of scales in juxtaposition, the idea of substitution may be graphically portrayed. Thus the relation of cups to pints is shown by the top set of scales in Figure 4. The relation of

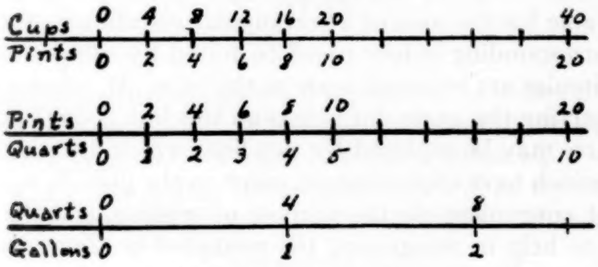

FIG. 4. Liquid measures.

pints to quarts is shown by the middle set of scales. The relation of cups to quarts is also apparent, and the scales of pints could be eliminated. In effect, the scale of cups and the scale of quarts can be "pushed together" and made adjacent scales with the space between them eliminated. This corresponds to the algebraic process by which the variable P is eliminated between the two formulas $C=2P$ and $P=2Q$ to produce the relation $C=2(2Q)=4Q$. If adjacent quarts-gallons scales are also shown on the diagram, the scales of quarts can be eliminated to show the relation $C=16G$.

Inverse relationships of the form $xy=k$ are easily recognized from adjacent scales, since a glance at the scales shows that as one variable increases, the other decreases. Thus the nature of Boyle's Law, the intensity of light as a function of distance, and similar relationships, may be clarified. A simple example is provided by the relationship

between uniform velocity and time for a constant distance, say 25 miles. The scales are shown in Figure 5. The $xy=1$ or reciprocal relationship may be shown to better advantage by use of adjacent logarithmic scales, similar to the C and CI scales on slide rules, for

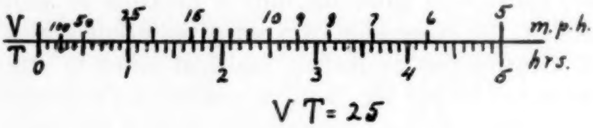

FIG. 5

log y and log $(1/x)$. The properties of logarithms make it possible to interpret the scale values for various positions of the decimal point, and in this way the range is greatly extended. Finally, by the use of adjacent log log scales greater precision is possible for a portion of the range, and the decimal points are fixed as to position in the scale values.

NON-ADJACENT SCALES

If two adjacent scales have the same zero point, and one of them is rotated about this point through an angle of ninety degrees, they become suitable for the axes of a rectangular coordinate system in the plane. Corresponding points could be found by using compasses to strike a circular arc from one scale to the other. If, however, a line is drawn bisecting the angle, for points on this line $f(y)=F(x)$, and the circular arcs may be replaced by two lines which are parallel to the axes and which have their common point on the line. As noted earlier, this is not convenient for the purpose of reading, and the 45-degree line is of no help in recognizing the relationship. Consequently, line graphs are usually drawn from uniform scales, so that the nature of the function can be shown by the *position* and *shape* of the resulting line or curve. The reading of corresponding values is of relatively less importance, and the impression should not be given that the major purpose of a line graph is to determine values of one variable when the other is known. The table used in making the graph, or a set of adjacent scales, is better for this purpose.

There are two important exceptions to the rule that uniform scales are preferable for line graphs. The first exception occurs when it is known that the relation is of exponential type, say $y=ae^{bx}$, or if there is reason to suspect this from the nature of the situation or from a study of the table of data. In this case a uniform scale is used for x and the non-uniform logarithmic scale is used for y. Since log $y=\log a+bx \log e$, if the data do satisfy an exponential law of the above type, they will lie at least approximately on a straight line when plotted on this coordinate system. Moreover, the y-intercept

and the steepness will depend upon the parameters a and b. Applications of this form are sufficiently numerous that printed scales for this purpose are commercially distributed, and every class which studies logarithms should have an opportunity both to make several such graphs and to interpret a few found in books. See Figure 6.

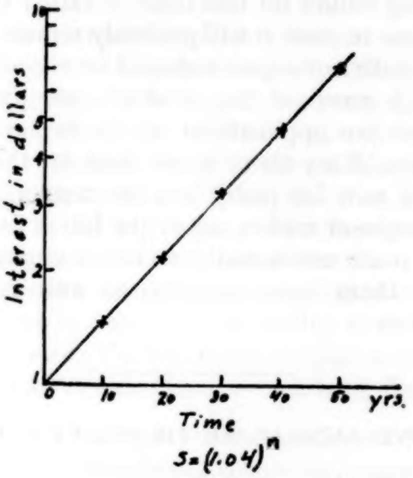

FIG. 6

The second exception occurs when it is known or suspected that the relation is of the type $y=ax^n$. In this case the non-uniform logarithmic scales are employed on both axes. For this relation $\log y=\log a+n \log x$, and if the data satisfy the relation they will be represented by points on a straight line on the coordinate system. In this case the

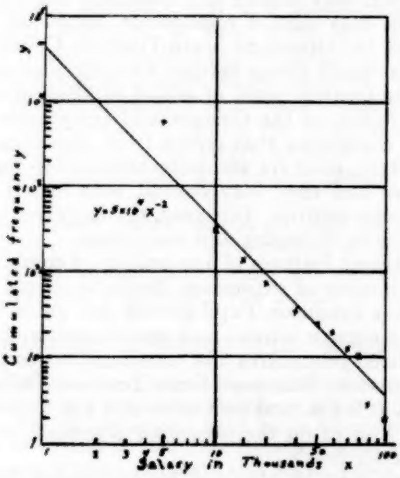

FIG. 7. Salaries received by executives in a corporation.

y-intercept depends upon the parameter a, and the steepness of the line depends upon the exponent n. Coordinate paper, usually called "log log paper," is available for this purpose. Students should see and draw a few graphs of this type also. See Figure 7.

Non-adjacent scales in the form of nomograms may be used for the purpose of reading values for functions of rather complicated structure. For some time to come it will probably remain useless to suggest that some work with nomograms should be included in high school courses. Although most of the students are probably aiming at careers which involve applications of the topics discussed above, many teachers would say there is not time for this material. There seems to be time now for many less interesting and useful topics. The successful engineer makes use of the latest developments in his field. Those who teach mathematics to future engineers would be well advised to give them some modern, as well as some traditional mathematical tools.

THE SECOND ANNUAL SOUTH JERSEY SCIENCE FAIR

The Du Pont Company, through its Chambers Works at Deepwater Point, will act as co-sponsor of the South Jersey Science Fair. The fair is being staged under the auspices of the New Jersey Science Teachers Association for the purpose of giving recognition to grade and high school pupils of South Jersey for achievement in scientific studies.

The fair will be held at the Glassboro State Teachers College next April 22. All pupils in the area may take part by submitting samples of their creative work in science for exhibit at the fair and for competition in the award of prices. As co-sponsor of the fair, Du Pont will donate awards to be made for the best exhibits. The nature of the awards is to be determined by the fair committee at a later date. Fair exhibits may feature any branch of science or may combine several branches. Pupils may obtain registration forms for entering exhibits by writing Dr. Haupt at the Glassboro State Teachers College.

The Second Annual South Jersey Science Fair provides opportunity for display and evaluation of the creative work of school children of all grade levels. Here, pupils may see the results of the thought and achievement of others and they may experience the confidence that comes from identification and appraisal of their own talents. Here, teachers and parents may see the varieties of abilities possessed by children and they may consult with experts concerning the best ways of developing such abilities. This year, the fair gives particular attention to the educational functions of display and evaluation.

Exhibitors may present features of any science or combination of sciences and they may utilize any mode of expression. Exhibits should embody the interests and inclinations of the exhibitor. Pupil growth and guidance are the major considerations. The Fair regards science as a manifestation of the human spirit and subordinates formalized procedures and classifications to pupil initiative.

The Fair will be held at Glassboro State Teachers College on April 22, 1950. The program begins at 9 A.M. and concludes at 4 P.M. Exhibits may be placed on the morning of the Fair or on the preceding afternoon or evening. The college cafeteria is available for lunch.

Registration forms may be obtained by addressing Dr. George W. Haupt, New Jersey State Teachers College at Glassboro.

THE ELEMENTARY SCHOOL SCIENCE LIBRARY FOR 1948–1949

PAUL E. KAMBLY
School of Education, University of Oregon, Eugene, Oregon

This sixth list of reference books for elementary school science is intended to supplement those previously published.[1] The purpose, like that of preceding lists, is to suggest to elementary school teachers, books that are supplementary to basic text series either for their values as sources of information or for recreational reading. The subdivision topics, similar to those used in previous lists, are of no significance except as an aid in grouping the references.

The grade levels indicated are the lowest in which it is recommended that the books be used. Exact grade placement is difficult because of variations in pupil reading ability as well as differences in how the books are used. The recommendations and the brief annotations are based on an examination of each book listed.

REFERENCE BOOKS FOR ELEMENTARY SCHOOL SCIENCE

Animals

(See also list of books on birds and insects)

	Grade	Price
Snakes. By Herbert S. Zim. 700 pp. '49. Morrow*.......... How snakes produce their young, how they grow and the ways by which they move. Very well illustrated. A good book that will help to convince students that snakes are worth protecting.	3	$2.00
Wild World Tales: The Tale of the Mouse, the Moth, and the Crow. By Henry B. Kane. 132 pp. '49. Knopf.......... This book contains the complete text and illustrations of three separate books published in 1940, 1942, and 1943. Beautiful full-page photographs illustrate each story.	3	2.75
Animal Weapons. By George F. Mason. 94 pp. Morrow...... Another excellent book by the author of *Animal Tracks, Animal Homes,* and *Animal Sounds.* Explains the weapons with which animals defend themselves or attack an enemy.	4	2.00
Animal Facts & Fallacies. By Osmond P. Breland. 268 pp. '49. Harper.. Includes information about fishes, mammals, reptiles, amphibians and birds. The question and answer form of writing is used. This book will help many elementary school teachers answer the questions their pupils ask. The author is a professor of zoology.	5	3.00
Barnyard Family. By Dorothy C. Hogner. 72 pp. '48. Oxford.	5	2.75

[1] Kambly, Paul E., "The Elementary School Science Library," SCHOOL SCIENCE AND MATHEMATICS, 44: 756–767, November, 1944. "The Elementary School Science Library for 1944–45," SCHOOL SCIENCE AND MATHEMATICS, 46: 13–16, January, 1946. "The Elementary School Science Library for 1945–46," SCHOOL SCIENCE AND MATHEMATICS, 46: 865–870, December, 1946. "The Elementary School Science Library for 1946–47," SCHOOL SCIENCE AND MATHEMATICS, 48: 202–205, March, 1948. SCHOOL SCIENCE AND MATHEMATICS, 49: 237–240, March, 1949.

* Publishers and their addresses are listed at the end of this section.

	Grade	Price
A chapter each on colts, calves, lambs, kids, little pigs, puppies, kittens, and little rabbits. Directions for care and feeding are included.		
Caribou Traveler. By Harold McCracken. 204 pp. '49. Lippincott	5	2.50
A biography of Tuktu, the caribou, in which the rigors of life in the Arctic are interestingly presented. Describes the thousand mile migration made yearly by the caribou.		
Kalak of the Ice. By Jim Kjelgaard. 201 pp. '49. Holiday	5	2.50
A good story about a polar bear whose home lay north of the Arctic Circle. Includes information about seals, whales, and walruses, and the men who live among them.		
Stolen Pony. By Glen Rounds. 154 pp. '48. Holiday	5	2.00
A good book for anyone that loves dogs and horses. Neither the dog in the story nor the pony ever acts like anything other than a real dog and a real pony.		
Vison, the Mink. By John and Jean George. 184 pp. '49. Dutton	6	2.50
A story with its setting in the hills of Maryland. Well written and well illustrated as was *Vulpes, the Red Fox* by the same authors.		
Birds		
Birds in Your Backyard. By Bertha M. Parker. 36 pp. '49. Row	2	0.48
Brief information on 23 common birds. One of the Basic Science Education Series.		
Maggie, a Mischievous Magpie. By Irma S. Black. 56 pp. '49. Holiday	3	1.50
A true story of a magpie that could talk. Primarily a story but should be useful in developing interest in pets.		
The Life of Audubon. By Clyde Fisher. 76 pp. '49. Harper	4	2.50
An interesting biography abundantly illustrated with beautiful reproductions of Audubon's work. 20 pages in full color and 53 illustrations in black and white.		
Homing Pigeons. By Herbert S. Zim. 63 pp. '49. Morrow	5	2.00
How anyone may acquire a loft and a flock of racing homers. Describes pens, nesting boxes and the care of birds. Also includes material on pigeon anatomy and physiology.		
Birds; A Guide to the Most Familiar American Birds. By Herbert S. Zim and Ira N. Gabrielson. 157 pp. '49. Simon	6	1.00
Information on how to use the book, how to observe birds, parts of a bird and bird classification. There are color plates illustrating 112 species.		
Conservation		
Wildlife for America; the Story of Wildlife Conservation. By Edward H. Graham and William R. Van Dersal. 110 pp. '49. Oxford	5	2.50
General Nature Study		
The Big Snow. By Berta and Elmer Hader. 48 pp. '48. Macmillan	1	2.50
A very attractive book. Information about many common birds and mammals of the Northeast is part of the story. The book is not entirely accurate from a scientific point of view but if properly interpreted is of value because of its general theme.		
Beginner's Guide to Seashore Life. By Leon A. Hausman. 128 pp. '49. Putnam	5	2.00

Grade Price

A pocket size book that pictures over 250 of the most common forms found on the east and west coasts of the United States and Canada. Simple keys are included and there is a section on objects found in the tide track.

General Science

Toys. By Bertha M. Parker. 36 pp. '49. Row 2 0.48
Toys illustrate certain principles of mechanics. Large-scale, colored illustrations that could be used as directions for actual construction. One of the Basic Science Education Series.

How Your Body Works. By Herman & Nina Schneider. 158 pp. '49. Young 3 2.50
An elementary physiology which includes experiments that are easily performed. Illustrated with line drawings. The emphasis is on a healthy body and how it can be kept that way.

Television Works Like This. By Jeanne and Robert Bendick. 64 pp. '49. Harper 4 1.75
A complete story of this new medium of communication.

Experiments with Electricity. By Nelson Beeler & Franklyn Branley. 145 pp. '49. Crowell 5 2.50
All the experiments depend on electricity supplied by dry cells. An excellent book for boys who need suggestions that supplement those given in basic text materials.

Stories in Rocks. By Henry Lionel Williams. 151 pp. '48. Holt. 6 3.00
A simply written geology text which answers questions about the formation of the earth and the materials found in the earth's crust.

The Stars Are Yours. By James S. Pickering. 264 pp. '49. Macmillan 6 3.95
A book written for laymen that answers questions such as: What are the stars? How far away are they? What are they called? What is their significance in the scheme of things?

Insects

Sphinx, the Story of a Caterpillar. By Robert M. McClung. 50 pp. '49. Morrow 1 2.00
Simple yet complete life history of a tomato worm. The story begins in June with the laying of eggs, and ends the following year when the cycle is completed.

Six-Legged Neighbors. By Bertha M. Parker. 36 pp. '49. Row. 2 0.48
Information about 35 kinds of insects, chiefly moths and butterflies. One of the Basic Science Education Series.

What Butterfly Is It? By Anna Pistorius. 25 pp. '49. Wilcox... 2 1.50
Includes many familiar species. Describes how a butterfly grows and presents the species in the order of their spring and summer appearance. The colored illustrations are excellent aids to identification.

Plants

Bits That Grow Big. The Story of Plant Reproduction. By Irma E. Webber. 64 pp. '49. Young 1 1.50
Information about plants and how they grow. Directions for simple experiments with seeds and spores. Well organized and well illustrated.

Leaves. By Bertha M. Parker. 36 pp. '49. Row 2 0.48
Leaves of common trees are illustrated and discussed. In-

	Grade	Price
cludes a section on autumn leaves. One of the Basic Science Education Series.		
Play with Plants. By Millicent E. Selsam. Illustrated by James MacDonald. 63 pp. '49. Morrow	3	2.00
A book of experiments with plants. How plants develop from seeds, how they use water and how they respond to light. Large type and graphic pictures. The book is planned as a science picture book for young readers.		
Green Treasure. By M. I. Ross. 173 pp. '48. Harper	6	2.50
The story of a boy, who got a chance to be cook's helper on a plant exploring yacht expedition around the world.		

Transportation

Going Up, The Story of Vertical Transportation. By Jack Bechdolt. 128 pp. '49. Abingdon	5	2.00
About inventions and inventors. Elevators, escalators, ski tows, ferris wheels, dumb waiters and other devices are included.		

Miscellaneous

Albert Einstein. By Elma Ehrlich Levinger. 174 pp. '49. Messner	5	2.75
This is the story of a boy who disliked school because he could not ask, "Why." A very interesting biography written simply enough for upper grade use.		
Bob Vincent, Veterinarian. By Edna Hoffman Evans. 192 pp. '49. Dutton	6	2.50
A story of a boy's adventures with animals. A book that should help to create interest in pets and a desirable attitude toward animals.		
Council Fires. By Ellsworth Jaeger. 253 pp. '49. Macmillan	6	2.95
A discussion of each step in planning and staging a successful council fire for either junior campers or adults. Includes appropriate games, contests, songs, stories and authentic Indian dances.		

PUBLISHERS AND THEIR ADDRESSES

Abingdon: Abingdon-Cokesbury Press, 810 Broadway, Nashville 2, Tenn.
Crowell: Thomas Y. Crowell Company, 432 Fourth Avenue, New York 16, N. Y.
Dutton: E. P. Dutton & Co., Inc., 300 Fourth Avenue, New York 10, N. Y.
Harper: Harper & Brothers, 49 East 33rd Street, New York 16, N. Y.
Holiday House: 513 Avenue of Americas, New York 11, N. Y.
Holt: Henry Holt and Company, Inc., 257 Fourth Avenue, New York 10, N. Y.
Knopf: Alfred A. Knopf, 501 Madison Avenue, New York 17, N. Y.
Lippincott: J. B. Lippincott Co., East Washington Square, Philadelphia 5, Pa.
Macmillan: The Macmillan Company, 60 Fifth Avenue, New York 11, N. Y.
Messner: Julian Messner, Inc., 8 West Fortieth Street, New York 18, N. Y.
Morrow: William Morrow and Company, 425 Fourth Avenue, New York 16, N. Y.
Oxford: Oxford University Press, 114 Fifth Avenue, New York 3, N. Y.
Putnam: G. P. Putnam's Sons, 2 West 45th Street, New York 19, N. Y.
Row: Row, Peterson and Company, 131 East 23rd Street, New York 10, N. Y.
Simon: Simon & Schuster, Inc., 1230 Sixth Avenue, New York 20, N. Y.
Wilcox: Wilcox and Follett, 1255 S. Wabash, Chicago, Ill.
Young: William R. Scott, Inc., 72 Fifth Avenue, New York 11, N. Y.

AN OPEN-BOOK OBJECTIVE EXAMINATION FOR SCIENCE COURSES

JACOB VERDUIN
Franz Theodore Stone Laboratory, The Ohio State University, Put-In-Bay, Ohio

The teaching methods used in our colleges and universities have received a considerable amount of criticism in recent years. Most of the criticisms are not very specific and seldom offer ways of improving our methods. The present paper represents an attempt by a science teacher to identify and correct a specific fault in the system. There are, doubtless, other important faults in our system, but the one selected is sufficiently widespread to warrant discussion, and its correction is fairly simple.

The fault ies in using closed-book examinations to sample student achievement. Most college and university science courses base the grading of students largely on closed-book examinations. Such a heavy premium is placed on memory that a student's ability to use information is seldom evaluated. While it is ideally true that student motives in studying should exceed the requirements of examinations, the fact remains that most students direct their study efforts into the channels which will insure passing grades. If the major part of our examining consists of sampling the student's memory store of factual information, then the primary objective attained in our courses will be the cramming of memory by the student. Such an objective is of questionable value. A student who is going to use facts should never trust so faulty a source as memory to provide them. He should consult a number of source books and/or publications to be sure that the set of facts he is about to use is correct. If he has used a set of facts several times those facts will be remembered but if a set of facts is committed to memory in preparation for an examination there is no assurance that the student is able to use those facts in any way—practical or aesthetic! Closed-book examinations, therefore, evade the function of factual information, since they encourage the memorization of facts without regard to proficiency in using them.

The closed-book examination has another unfortunate influence. Since the student is to be graded on his store of memorized facts it is only fair that the professor should emphasize the facts which are worth remembering (i.e. are likely to be included in examinations). The activities of the teacher are then largely restricted to selecting, abridging, and synopsizing, the ever-increasing volume of facts included in the scope of his course so they can be fitted into the lecture time allotted. (The lecture method is still almost universally used in

colleges and universities although the invention of the printing press rendered it quite obsolete.) It is a familiar experience for a professor to confirm the suspicion that students are not reading text and reference material. It is equally common among students to hear the brag, "I passed that course without cracking a book." These situations are produced by the professor's excellence in the futile activity of condensing, selecting, and over-emphasizing subject matter in lecture. The fact that very little of this carefully selected and condensed material is retained by the students for more than a few weeks or months points up the futility of the procedure and is convincing evidence that the students have found no use for the information.

The evils associated with closed-book examining can be attacked by adoption of open-book examinations. In such examinations the emphasis on memory is removed and the effective course objectives become much more profitable. Student energies can be directed toward familiarization with sources of information, understanding and integration of facts, and practice in utilizing facts by problem-solving. Facts which are used in solving problems soon become a part of the student's thinking equipment. The ability to find information also becomes important—a skill not presently acquired in many courses! The efforts of the professor can be turned to planning problems and exercises which will promote these more profitable objectives, since the need for emphasizing material to be memorized has been removed. Neither is it necessary any more to "cover all the material" in a course. The student is being equipped to find and use information so he will in the future be able to obtain information he needs even though that information was not stressed during his course work. The goal of teaching then is to make the students as nearly independent of the teacher as possible.

In attempting to apply the principles described above to plant science teaching (college freshmen) the author designed open-book tests of the objective type. An open-book examination which contains the statistical inadequacies of the subjective type test, while it might be a valuable exercise for the student, would not be defensible as a means of grading the student. The open-book objective type tests were given twice during each semester, at the time assigned for mid-semester and final examinations. These tests contributed one-fourth of the student's final grade. The other three-fourths was obtained from six "lab practical" type tests, each two hours in length containing approximately one hundred questions cast in multiple choice form. Materials were brought into the laboratory and the questions applied to them. For example, a twig would be placed opposite a sheet of paper bearing the legend:

(a) opposite compound leaves
(b) alternate compound leaves
(c) opposite simple leaves

or a pine branch would be associated with the legend:

These leaves have morphological characteristics which—
(a) prevent rapid water loss
(b) prevent high rates of carbon dioxide absorption
(c) both (a) and (b)

One minute was allotted for each question. This "lab practical" type of test is familiar to most science teachers and need not be discussed in further detail. Such tests do not usually contribute the bulk of the student's grade, however, so it should be mentioned that these examinations were adequately monitored to minimize "lifting" of answers from neighbors (an evil inherent in all objective type tests). An effective deterrent to "lifting" of answers was fashioned as follows: all examinations were made so difficult that the best paper in the class usually had a half dozen errors or more. When answers are "lifted" the errors are "lifted" with the correct answers and when one considers that the probability of two students making the same five errors accidentally is 3^{-5} (assuming multiple choice questions with three possibilities) it is apparent that evidence soon becomes overwhelming. The monitor's duty then merely consists of reporting to the instructor which papers are likely to need comparison. When this method of collecting evidence was explained to the students "lifting" became negligible. The above discussion of the "lab practical" test is presented because a comparison will be made later between the grades so obtained and those obtained on the open-book objective examinations.

Three sample problems of the type used in open-book objective tests are presented below.

A. Each of the sentences below is made up of a statement followed by a reason introduced by the word *because*. If a statement is false cross out an (F) on your answer sheet. If a statement is true and is well supported by the reason cross out a (T). If the statement is true but the reason given is inadequate cross out an (I).

1. The bacteria are considered to be relatives of the blue-green algae because they lack nuclei and multiply by fission.

2. The slime molds are classed as plants rather than animals because their energy requirements (respiration) are like those of plants.

12. A plant like Fucus (p. 381) is properly called heteroecious because male and female gametangia are produced on different individuals.

The page numbers refer to pages of Holman and Robbins' Text-

book of General Botany. A problem of this sort usually contained fifteen statements. The sample statements given should be classed (T), (I) and (F) respectively. One of the advantages of open-book testing lies in the greater scope of testing material. For example, the twelfth statement in a closed-book examination might be missed because the student had forgotten the definition of heteroecious, and one might argue that its meaning is not important enough to be included in a freshman's vocabulary, but in an open-book test the student may look up definitions and the questions will test his ability to apply them in detecting the acceptable answer.

B. Turn to the diagram in figure 297, p. 402. (This is the familiar carbon cycle diagram.) Read the statements below. If a statement is false cross out an (F) on your answer sheet. If a statement is true and is supported by the diagram cross out an (S) on your answer sheet. If a statement is probably true but is not supported by the diagram cross out a (T) on your answer sheet.

1. Before plants or animals existed on earth the air must have been entirely free of carbon dioxide since respiration is the only source of atmospheric carbon dioxide.

7. The rate of photosynthesis could probably be increased by increasing the carbon dioxide content of air.

13. Photosynthesis is the source of carbohydrates for both the plant and animal kingdoms.

These three statements are (F), (T), and (S) in that order. Some students find the first question difficult because it not only is false but the diagram proves it to be false so they are sure it should be in a special category. The seventh and thirteenth statements are both true but some students do not realize that the thirteenth one is supported by the diagram. Problems of this type are relatively easy to write and they focus student attention on the illustrative material in a text. It is amazing to discover that many students in reading their text will ignore all illustrative material, as if knowledge were to be gained only from the printed page!

C. A man wanted to know whether his poor radish seed germination was caused by a pathogenic organism in the soil or by improper storage temperature, so he treated five samples of seed as indicated in the table below and got the results shown in the right hand column.

Read the statements below. If a statement is supported by the data in the table cross out an (S) on you answer sheet. If a statement is contradicted by the data cross out a (C). If a statement goes beyond the data and is neither supported nor contradicted cross out an (N).

4. Plants grow better when the soil is warm, about 25 deg. C

Sample	Stored at	Planted in	Germination %
1	normal (10 deg. C.)	ordinary soil	47
2	normal (10 deg. C.)	steam sterilized soil	88
3	0 deg. C.	ordinary soil	50
4	15 deg. C.	ordinary soil	49
5	25 deg. C.	ordinary soil	15

All other conditions uniform for all samples.

5. The data indicate that the cause of poor germination was largely removed by steam-sterilizing the soil.

14. The experiment did not shed any light on the man's problem.

The statements above are classed (N), (S) and (C) in that order. Problems of this type measure a student's ability to draw conclusions from data. If these problems are practical, simulating the sort of situations faced by college graduates in their jobs, the value of the problems is enhanced. Any course which tries to give students an appreciation of the scientific method should include such problems in the testing program.

The sample problems show that the writing of open-book objective tests is not radically different from, and no more difficult than the composition of closed-book objective tests. It is only necessary that the problems designed present questions which are not directly answered by the text. If they are one is merely measuring ability to locate the answer. Such ability, however, is worth measuring—one could argue successfully that it is more worthwhile than memory testing! The novelty of the open-book test lies in its wider scope and in its release of the student and teacher from the unfortunate drive toward memorization.

As a means of grading the student the open-book objective type test was entirely satisfactory. The range of errors was as large as on the "lab practicals." In a representative examination containing one hundred questions the range of errors was 54-7, and the median number of errors was 24. In the table below the grades of ten students for one semester's series of tests are presented (best paper = 100).

The students in the table ranged all the way from superior to failing. The open-book objective tests (columns marked with an asterisk) classed the students in essentially the same grade category as did the "lab practicals." Students numbered 5 and 6 were included in the table as exceptional examples. Student 5 did less well on the two open-book tests than on most of the "lab practicals," while student 6 made his highest grades of the semester on the two open-book tests. Even in these two cases, however, the differences may be

accidents of sampling. They represent two cases out of 186 students who were exposed to the system during four semesters.

TABLE 1. GRADES OF TEN STUDENTS FOR ONE SEMESTER'S SERIES OF TESTS

1.	79	80	71*	83	66	70	75	76*	C
2.	61	60	78	63	64	68	66	64	D
3.	99	94	100	98	98	100	98	100	A
4.	89	86	88	85	91	98	90	95	A
5.	84	60	60	70	72	95	74	66	C
6.	76	62	80	77	74	74	74	82	C
7.	89	90	83	83	79	70	82	83	B
8.	61	66	66	70	71	51	66	72	D
9.	79	82	78	88	88	75	82	79	B
10.	66	56	51	61	55	59	58	66	F

Under the grading system in use at the University of South Dakota a final average of 91–100 = A, 81–90 = B, 71–80 = C, and 61–70 = D. Numerical grades for each examination were determined by the formula:

Grade = 100 − PF, where P = number of errors minus number on best paper in class, and F = median P divided by 25.

New examinations were prepared for each test period so students having access to files of previous examinations did not enjoy any detectable advantage.

A noticeable change in attitudes was apparent as the students became convinced that memorization was no longer the first course objective. The above-average students took advantage of the opportunity for broader study, motivated somewhat, perhaps, by the fact that some questions on the examinations were more adequately discussed in reference readings than in the text. The below-average students often said that they much preferred closed-book examinations and were sure that they could get better grades on such tests. This may have been simply the familiar "greener pastures" reaction, but it is entirely possible that a sub-average student can by hard work memorize a considerable amount of so-called factual information although his understanding of it may be negligible.

The good agreement between grades obtained in "lab practicals" and in open-book objective tests shows that the advantages of open-book testing can be realized without sacrificing any accuracy in scoring the student. While numerous instructors appreciate the values of open-book testing they usually make their tests of the subjective type, thus seriously impairing their accuracy as a grading device. The data presented here show that when the advantages of open-book testing and objective design are combined the product is a valuable teaching and testing tool.

One of the greatest advantages of open-book testing derives from abandoning the lecture method and devising a routine which pro-

motes understanding and utilization of subject-matter by the students. Every instructor should, of course, devise routines and exercises which are best suited to his own tastes and abilities, but a brief description of the method used in conjunction with the examination program outlined above may provide useful suggestions. The routine to be described occupied one-third of the student-contact time. The two-thirds represented by laboratory periods were regarded as the major contribution of the course.

The routine was as follows: Text and reference book assignments were made, and a set of thought problems was submitted to the students each week. Answers to these were to be composed by the student and returned at the next class session. (Thus one frequent and valid criticism of objective type testing—namely, the lack of opportunity for expository writing, was met.) These exercises did not contribute to the student's grade, and only a fraction of the papers submitted was read by the instructor each week. The problems were made a basis for group discussion during the two one-hour periods per week devoted to this routine. Sometimes discussion was provoked by such under-handed methods as the reading of a particularly bad student analysis of a thought problem. At other times the problems evoked such a variety of ideas that discussion was spontaneous. During the first several weeks of this type of treatment there was a tendency on the part of many students to regard the instructor as an oracle. Their discussion of thought problems, they felt, must be a preliminary activity of little significance which would be followed by the *ex cathedra* of the instructor. Attempts to discourage this attitude were made by avoiding direct answering of questions and either referring the student to the sources of information which would provide the key to his question, or calling on various members of the class to discuss the question until whatever logic was involved became clear. Perusal of the written answers to problems helped the instructor to know which students would be likely to guide the class to the best solution in a particular case. An attempt was made to include some thought problems in each week's assignment which were not capable of definitive solution. When discussion of such problems became satisfactorily confused an admission by the instructor of similar confusion served to dampen student reverence to some extent.

Some sample thought problems are presented below: In an assignment including the study of mushrooms—(1.) Mushrooms frequently grow in "fairy rings." The grass under such a ring is pale and weak, while the grass just inside the ring is green and vigorous. My great-grandfather said the "Wee People" danced under the mushrooms at night causing death of the grass. Can you think of a better explana-

tion? In an assignment including discussion of photosynthesis—(2) It is a convention in organic chemistry to include all the materials which are "used up" in a reaction on the left hand or "raw materials" side of an equation, while catalysts are bracketed above the arrow. Write the photosynthesis equation in its most acceptable form including CO_2, O_2, $C_6H_{12}O_6$, H_2O, light, chlorophyll, other enzymes. In an assignment including discussion of hereditary factors—(3) The xylem and phloem in a tree are very dissimilar tissues. Discuss possible causes for the dissimilarity. From what tissue(s) do they originate? What type of cell division is responsible for their production? How do hereditary factors (genes) influence this problem? Problem (3) is an example of the type in which the instructor must confess that he doesn't know all the answers. The questions at the ends of chapters in texts and lab manuals provide source material for this type of routine. All of the concepts which would be worked into a traditional lecture can be woven into a problem set and by conscientious direction of student discussion a higher level of mental participation by the student can be obtained than is likely to exist under the lecture system.

The sample open-book test problems presented above are presented only to show that they represent a modification of a familiar vehicle which is easy to construct. Most of the varied and excellent problem types which are widely used on standard achievement tests can be adapted for open-book testing. Also the routine described above to displace the traditional lectures is only one of many which could be devised. The foremost gain provided by abandoning lectures is the opportunity for improving the students' attitude toward their studies. A discouraging number of students visualize their educational years as a period during which they will learn everything they must know to acquire and hold the job they want. The rest of their life then, they believe, will be spent applying the knowledge they obtained at school. This erroneous attitude is the basis of the familiar alumnar lament, "I haven't used one per cent of the things I studied in school." This erroneous attitude is aggravated and perpetuated by the lecture method in which the professor parades himself before the class and tells them all the "answers." Abandoning the lecture method removes the emphasis from the "answer" and places it on the process by which the "answer" is obtained. Subject matter then is merely the material on which the student exercises while acquiring skill in studying, and the role of the instructor is to supervise the study process—not to circumvent it by providing the "answer."

The educational objectives emphasized above are familiar and have been widely praised, but it seems that the frustrating effect of the closed-book test and lecture method have not been appreciated.

It seems likely that adoption of open-book testing programs and abandonment of the lecture method will improve the effectiveness of any course in which an attempt is made to achieve the more profitable course objectives made possible thereby. Although this discussion has dealt exclusively with college-level teaching methods there is no reason to believe that open-book testing would not be successful if applied to high school courses.

EXPERIMENTS FOR THE EARTH SCIENCE CLASS

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WHAT FREEZING WATER DOES TO ROCKS

The action of freezing water produces vast changes on the surface of the earth. It is indeed a tremendous agent. It produces great layers of loose rock on mountain sides (called talus) and this disintegrated rock eventually becomes soil. To demonstrate the forces developed when water freezes in the cracks in rocks arrange the following:

Take a small medicine bottle, fill it with water, and cork it up firmly. Better still, use a bottle that has a screw cap. Now place this in a large beaker of cracked ice and salt. The water in the small bottle shortly freezes and the bottle bursts. This is exactly what happens when water freezes in cracks in rocks. The pressure developed in the expansion of freezing water is of the order of several thousand pounds per square inch!

COOLING BY EXPANSION

Introduce some warm air or smoke into a large flask. This can easily be done by holding a burning match or candle at the mouth of the inverted flask. Now quickly pour a few drops of alcohol into the flask and more quickly still stopper it up. Shake vigorously. The alcohol vaporizes. The pressure in the flask increases. Now quickly remove the stopper. The gases rush out. The sound may even be distinctly audible. This rapid expansion produces substantial cooling and dense fog is produced. This identical phenomenon takes place on tremendously large scale in atmospheric processes.

Laboratory hot plate, electric type, provides stepless heat control and, after attaining a surface temperature of 500 degrees Fahrenheit, consumes current only 50% of the time. Heating elements, of the flat type which prevent "cold" spots, are completely embedded for safety.

COOPERATIVE PLANNING IN TEACHER EDUCATION*

(REPORT OF THE A.A.A.S. COOPERATIVE COMMITTEE ON THE TEACHING OF SCIENCE AND MATHEMATICS)

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In recent years there has been an increasing and encouraging recognition of the place and importance of the teacher in American life. Furthermore, the crucial role that science plays in our modern technological society has directed particular attention to the important place of the teacher of science and mathematics. This increasingly important role of the science and mathematics teacher has made it not only desirable but imperative that careful thought and study be given to the program of teacher education in science and mathematics.

Teacher education has developed through several stages, each with its particular emphasis. In the first stage it was assumed that specific and specialized study in the field to be taught would automatically result in competent teaching and educational planning. Later the development of schools and departments of education and their marked expansion lead to a considerable emphasis on the techniques of teaching, classroom management, testing, and all of the related aspects of professional education. Critics of this development have often suggested that it resulted in an over-emphasis upon methods of teaching and in the education of people who had elaborate training in the problems of classroom management but very little knowledge of subject matter. In some instances this criticism has been justified. There is little purpose in arguing the relative merits of these approaches. Certainly no person would question the need for the teacher of science, mathematics, English or any field having an adequate and comprehensive understanding of the teaching field. However, it is also submitted that competent teachers also must have a genuine understanding; of the nature of development and needs of children and adolescents; of the appropriate learning activities for these stages of development; a knowledge of the purposes and organization of the social institution in which they work; and skill in selecting, organizing, and directing classroom activities. In other words, teacher education is a total problem involving general education, education in the specialized field and professional education. The problem is that of the proper balance and integration of

* Presented at the Central Association of Science and Mathematics Teachers, November 25, 1949.

the total program. The development of such a program obviously requires the cooperative efforts of those whose primary interest is in the subject fields and those who work in the professional field of education. Departmental isolationism, either-or arguments and mutual distrust or disdain will contribute little to the improvement of teacher education.

In terms of this briefly reviewed setting it is appropriate to review the organization, purpose, and work of The Cooperative Committee on the Teaching of Science and Mathematics. The committee was organized in 1941 by representatives of several scientific societies to cooperatively study problems related to instruction in science and mathematics. After three years, the committee was reorganized as a committee of the A.A.A.S. The committee now is composed of representatives from the major national scientific societies and science teaching societies at both the university and secondary school level. Representatives on the committee keep the parent societies informed of the activities of the committee. As you know, Mr. Arthur O. Baker of the Cleveland Public Schools, is the able representative of the Central Association of Science and Mathematics Teachers. The present chairman, Dr. Karl Lark-Horovitz, representative of the American Association of Physics Teachers was instrumental in the founding of the committee and has provided creative and dynamic leadership for the work of the committee. Thus at a time when the need for cooperative work is being recognized, the committee has provided a means on the national level for implementing this need.

It is not the purpose of this report to summarize all of the activities of the committee which has given consideration to many problems of the curriculum in Science and Mathematics at the university and secondary school level, as well as to the program of teacher education in these fields. Volume four, *Manpower for Research,*[1] of the report to the President by the President's Scientific Research Report contains a comprehensive review and appraisal and submits proposals relative to education in science and mathematics in the elementary and secondary schools of this country. This review was prepared by the Cooperative Committee. Those interested in this field of education might profitably read this report with care.

In the balance of this paper it is proposed to present certain selected recommendations of the committee regarding the education of teachers of science and mathematics and to review the implications of these recommendations. The interpretations are in some degree those of the speaker and are not necessarily the precise interpretations of

[1] The President's Scientific Research Board. *Manpower for Research.* Volume four of *Science and Public Policy*. Appendix II "The Present Effectiveness of our Schools in the Training of Scientists." Government Printing Office, 1947. (Copies may be obtained by writing the chairman of the committee, Dr. Karl Lark-Horovitz, Department of Physics, Purdue University, Lafayette, Indiana.)

the individual members of the committee although it is hoped that they represent judgments approximating those of the committee. The selected recommendations which follow may be found in the previously mentioned report, *Manpower for Research.*[2]

The first of these deals with the education of the elementary school teacher. The recommendation briefly stated suggests *that the four year college course of the potential elementary teacher include six semester hours of biological science and six semester hours of physical science, each with professionalized laboratory work, and a professional subject matter course in mathematics. Teachers of seventh and eighth grade mathematics and general science should meet the requirements for certification in the secondary schools.* This recommendation is an outgrowth of the growing realization that a program of education in science should be a continuous program extending from the elementary school through the university. It is at the elementary school level where the potential future scientist should have the first opportunity to come in contact with the stimulating and imaginative area of science and mathematics and begin to develop an understanding of the opportunities in these fields. The actual identification of youth with a high order of potential ability in science can begin in the elementary school.

The program of education in science and mathematics at the elementary school level should not, or cannot be highly specialized. The aim should not be to provide mastery of specialized subject matter but to develop interests and the beginning of understanding of scientific and mathematical principles. It is also true that the exploratory work in these years will contribute to the development of attitudes and interests in science which may determine the career of the student in these fields for attitudes can be developed at this early age as at no other time.

Science in the elementary school suffers because many elementary school teachers have felt insecure and ill at ease in this field and often have had little preparation. It is obvious that you cannot expect the elementary school teacher in a program with many other demands upon her time to become a specialist in science and mathematics, but it is possible by providing the right kind of science courses at a university level to give the potential elementary school teacher some understanding of the materials and methods of science and of the nature of scientific experiments. This background will not be most effectively developed by one or two specialized courses in science which are provided primarily for the first course for the student who will major and specialize in a particular science. Science courses for the elementary school teacher should be developed for particular

[2] *Ibid.*, pp. 108–109.

purposes and needs of the teacher. The planning of such courses requires people who are familiar with the problems of the elementary school and people competent in the fields of science and mathematics.

Another recommendation deals with the program of preparation of the potential secondary school teacher of science and mathematics. Recommendations in this area deal with a number of different items. It is recommended ***that certification should be in a closely related subject within the broad area of science and mathematics.*** Anyone familiar with the general pattern of teaching assignments and certification recognizes that it is necessary for the average secondary school teacher to prepare in several different subject areas. A small school cannot provide a full time program for a teacher of physics, a teacher of chemistry, and a teacher of biology. Frequently teachers are certified in highly unrelated areas. Consequently, in many cases the teaching of science and mathematics is carried on by a number of teachers, each of whom may have their major interest in another subject area. Thus, science and mathematics as a broad area of work extending through the secondary school is not developed as a coordinated program because of the lack of leadership and because no teacher or group of teachers are directly responsible for the development of this work. By certification in closely related areas it should be possible to have a teacher of science and a teacher of mathematics in even the small high school.

Certification requirements and the undergraduate program in teacher education can be planned to achieve this end. The committee recommends ***that approximately one-half of the undergraduate program for the bachelor's degree should be allotted to preparation in the comprehensive teaching areas of science and mathematics; that each prospective teacher of science and mathematics should complete basic courses in biology, chemistry, mathematics, and physics; that the comprehensive area should include study beyond the basic course in at least two and preferably three of the sciences, with a minimum of 18 semester hours of study required for certification in a subject.*** Such a program of preparation should provide teachers capable of giving leadership in the development of a total program extending beyond any single subject.

This proposal for certification has really grown out of a concept of the function of science and mathematics in the curriculum of the secondary school and the pattern of organization needed for the development of work in the fields. A majority of students complete their education in high school. For these students it is necessary to develop a broad understanding of the field of science and the part it will play in their lives. At the same time the program should provide for the development of interest and provide some initial preparatory work for the gifted who will carry on in our scientific laboratories and

research work. It is necessary to give youth an opportunity to explore broadly the fields of science and mathematics and to develop an understanding of their own ability and talents. Thus it is desirable that the teacher of physics have a broad understanding of the relationship of that field to biological science, mathematics, and chemistry and to applied fields in industry. In the same manner the teacher of mathematics needs to know broadly the concepts and the applications of mathematics to the fields of scientific endeavor. Regardless of the particular field of special interest, the secondary school teacher needs to be truly a teacher of science or a teacher of science and mathematics. Teachers with this type of background would be much more likely to develop the understanding in science that is needed by all citizens and provide the initial stimulus and training for those people who will continue their education and contribute to theadvancement of science.

Another recommendation is to the effect *that the curriculum for the training of teachers should provide professionalized subject matter courses in biology, chemistry, mathematics, and physics; that these courses should be planned cooperatively by the subject matter department and the education department and taught in the subject matter department by an instructor experienced with secondary school teachers.* The definition of professionalized subject matter courses is at times somewhat vague. Essentially, it is an attempt to combine the study of teaching problems with the study of content. It requires a teacher with a background in both fields of study. There are problems which are not peculiarly those of education or of the scientific subject matter field which deal with the matter of organization of material, development of laboratory materials, the design and use of equipment. These courses when taught by those who have a little or no experience in the secondary school field and with only limited understanding of the nature and needs of the adolescent population in the typical school often fail to serve their proper purpose. But the professionalized subject courses must be developed by people who are also thoroughly and completely familiar with the subject matter of the scientific field itself. There is a need here for genuine cooperation. It might even be suggested that this area of work is a true interdepartmental responsibility and that there are people available for university staffs who might hold joint appointments in both education and the subject matter department. At the present time at Purdue University joint appointments have become a matter of policy and in the field of mathematics and physics we now have people, able and competent in those fields and recognized members of the subject matter department and also of the education division, who are devoting their time to the development of the kind of pro-

fessionalized subject matter courses which have been suggested here. We hope as time goes on to expand this type of joint appointments to other fields.

Another recommendation of the committee is to the effect *that there should be in-service education programs for science teachers in the public schools which are jointly planned by the administrative and supervising teaching staffs of the school in cooperation with the personnel from the State Departments of Public Instruction and the universities.* Science today is a dynamic and ever changing field. New laboratory equipment and materials are constantly being developed. Teachers of science and mathematics in most schools often find it difficult to keep abreast of new developments. It is, therefore, suggested that science and mathematics counselors might be appointed on a state-wide basis—out of the state department or out of designated universities who might make it their primary function to bring together teachers of mathematics for one or two day discussions of their problems, to visit schools, and to offer suggestions on materials. This kind of day by day working relationship on a purely in-service basis can contribute to the growth and development of the science teacher and contribute to the improvement of the curriculum in science and mathematics. It should be stressed that such in-service training programs should be strictly separated from any inspectorial or administrative responsibility.

The committee has given consideration and made suggestions regarding the development of an adequate program for the fifth year of work in teacher education. The fifth year level of education is obviously the minimum standard which all secondary school teachers must meet in the near future. Again this is an area which requires the cooperative work of both the Schools of Education and the subject matter department. This fifth year of education should ideally involve both work in advanced professional courses and graduate courses in the sciences and mathematics. In the judgment of the speaker one of the difficulties in providing adequate graduate work in the subject matter fields for teachers who undertake graduate work has been that the typical graduate offering in mathematics and sciences has been designed primarily for the professional research worker. Certainly, it should not be suggested that the secondary school teacher is interested in courses any less profound in purpose or less rigorous in nature. However, the secondary school teacher needs broader types of graduate offerings and courses in several fields within a science or in different sciences rather than a sequence of narrow and highly specialized courses. Therefore, it would seem that the proper implementation of this recommendation or suggestion does require that science departments give genuine attention to the

design and development of courses especially prepared for teachers at the high school level. Experience has proved that this is a challenge to the staff in the science departments of the universities of this country and that there are able people who are willing to give their time and efforts to the design of this type of work. Often this kind of work has not been adequately developed because of the lack of leadership to coordinate and stimulate the potential resources of the universities.

The preceding paragraphs have given a sketchy review of what I judge to be major recommendations and suggestions of the cooperative committee on the improvement of teacher education in science and mathematics. Two essential ideas should be stressed in closing this discussion. First, there is the imperative need of developing ways and means at the national, at the state, and at the local level that can bring about consideration of teacher education and curriculum development in science and mathematics. The cooperative committee has provided a means for cooperative study at the national level. Comparable groups at state and local level in the public schools and the universities must be developed to put actual programs into effect. A second essential idea is that curriculum development and teacher education are one total problem and the key to the improvement of education in science and mathematics lies in the long run in the selection and education of teachers.

Our age is known as the age of science. As in no other period there is a growing recognition in the minds of all people of the crucial need of scientific study and scientific understanding. The public is willing and able to support a program which will give really adequate instruction in these fields. Those of us who are in the professional field have a real opportunity to develop the kind of program which will insure scientifically literate citizens and provide for identifying able students who will tomorrow be our scientists and will hold in their hands the responsibility for the continued scientific developments upon which our whole culture is based.

1500 NEW UNIVERSES DISCOVERED IN SKY

Fifteen hundred new universes or galaxies of stars, each similar to our Milky Way, have been discovered in a Harvard astronomical survey of the big dipper region of the northern sky. Dr. Harlow Shapley, director of the Harvard Observatory, reported at the American Association for the Advancement of Science.

These great stellar systems are only a fraction of those that exist undiscovered in space. Dr. Shapley estimated that in the bowl of the great dipper alone there could be discovered a million galaxies, many so distant that light takes a thousand million years to reach the earth from them. Each contains more than a million stars like our sun. These new universes could be discovered by the 200-inch telescope on Palomar, using longest possible exposures with fastest photographic plates.

MATHEMATICS, TANGRUMS, TOOLS, TEMPLATES, AND TONGUES*

PAUL L. TRUMP
University of Wisconsin, Madison, Wis.

A tangrum is an old Chinese puzzle made by cutting a square in a certain way. The resulting pieces consist of five triangles, a smaller square and a parallelogram. These figures can be placed together in various combinations so as to form others. One could spend considerable time discovering various of the possible combinations. The search for a particular combination pattern might prove very elusive.

A puzzle is very intriguing, particularly if you know someone else has solved it, and you are stimulated to demonstrate that you're as good as the next fellow. Puzzle solving activities are usually of the trial and error variety. Either visually or actually you try various possibilities, more or less at random. You discard and select and, with a little luck, you are successful. There is usually a combination of embarrassment, bewilderment, perplexity, confusion, uncertainty, guesswork, mystery, and surprise.

A good puzzle is one in which the "secret" is well hidden. The solution often appears simple if someone shows you the "secret." Solving one puzzle is usually of little help in trying to solve another.

There is a certain amount of the puzzle aspect in many difficulties we meet. Perhaps one measure of a person's lack of educational development, however, is the extent to which he approaches difficulties as one normally solves a puzzle rather than with a "problem solving" approach. A measure of success in teaching mathematics is the extent to which learning is made a meaningful experience rather than an activity of the puzzle variety. In order to increase the effectiveness of learning in mathematics, many good analyses of problem solving abilities have been made. One test of such an analysis is the extent to which it helps develop behaviors which are clearly distinguishable from those of the "puzzle solving" variety.

Mathematics and puzzle solving have little in common except for incompetent teachers and the unfortunate casualties of our instructional programs. What then is mathematics? It has been frequently referred to as a tool subject.

A tool is an implement or instrument used manually to facilitate a mechanical operation. It is not a part of the finished product. The observer of the finished product might be very much puzzled to discover how the operation was performed. He may be able to duplicate the result without the proper tools but with much loss of

* Delivered at the meeting of the Iowa State Secondary School Principals Association, Des Moines, Iowa, November 4, 1949.

time. He might find that even though he has the information as to the tools useful for the operation, he needs additional instruction in their use, or practice in developing necessary facilities.

In order to determine the total cost of a dozen cans of peas you may use a memorized multiplication table as a tool. Without using this tool you could reason thus: if each can costs 43 cents, then two cans cost 43 cents more than one can. Three cans cost 43 cents more than two cans. . . . Seven cans cost 43 cents more than six cans, etc. By this simple induction you reach the conclusion that successive additions of 43 cents will bring you eventually to the total cost. Or you may reason that the total cost equals the sum of the individual costs, write twelve 43's in a column and add the figures all in one operation. If you take advantage of the multiplication tables as a tool *and* if you reason correctly, you recognize that the sum of twelve 43's is precisely what is meant by 12×43 and you proceed to multiply.

The use of the tool enables you to obtain the result more quickly. You must know the multiplication and addition facts and also a proper arrangement for putting down the products and sums. But first you must know that the answer to your problem can be obtained by multiplying 12×43. We should not be so intent on the use of the multiplication process as a tool here that reasonings referred to above are by-passed. Emphasis on mathematics as a tool subject is largely responsible for the question which comes from pupils all too often: "Do you add or multiply the numbers given in this problem?"

The emphasis on meanings and understandings which has recently characterized discussions on learning problems in the study of arithmetic makes an important contribution. It is the result of more clearly recognizing what mathematics is. An adding machine is a tool which enables you to do many computations with ease and speed. You need not know how it works. The inventor and manufacturer of the computing machine have developed the mechanics of the tool. The most essential aspects of the problem solving process are, however, still provided by the operator or the one who tells the operator what to do. The skills and processes on which we drill boys and girls in arithmetic can serve the same tool role of the adding machine for those who haven't machines at their disposal. Instruction based on that role alone meets a double hazard. A skill is of no service to you if you do not know *when* to use it. Learning based entirely on such an emphasis also proves to be an inefficient way of teaching and fixing the skill as a tool.

A template is a gauge, pattern or mold, used as a guide to the form of the work to be executed. A dressmaker's pattern is laid on a piece of cloth to guide the dressmaker in cutting out the cloth. If you wish

to know how much woven wire fencing you must buy in order to make cylindrical guards to place about some shrubs, you call upon the formula $c = \pi d$. Knowledge of this formula and its use equips you with a pattern of procedure. This pattern is very flexible. It is useful in any problem which requires that you find the length of a circle with known diameter. It also enables you to reverse the process and find the diameter of a circle whose circumference is known. Many problems are solved by such use of a formula expressing a relationship between variables in the problem. The formula provides a pattern. Facility with mathematical tools or skills enables you to use the formula to accomplish your purpose.

Mathematical studies should provide the student with patterns of procedure which will be of assistance in finding answers to his questions. It should provide him with the tools necessary in the use of those patterns. It should enable him to approach his problems in a forthright and intelligent way rather than with a "puzzle" solving approach. This implies thorough understandings of essential meanings and also accurate facility in the skills involved.

When we think of mathematics we frequently think of certain algebraic processes, arithmetic skills, geometric theorems or such special things associated with mathematical vocabulary and skills. This is analogous to thinking of music as notes, staffs, time signatures and practicing scales. It is analogous to thinking of literature as grammar, spelling and noun declensions. If all of our attention in teaching reading and written and oral expression is limited to the skills and mechanics of such activity, and does not give consideration and emphasis to the ideas expressed, our instruction is sterile. It is equally true that effective oral and written expression as a means of communication makes demands on the essential skills.

A tongue is the language of a people. Mathematics is a universal language. It provides the means of expressing quantitative relationships in precise form. It provides not only the tools and templates of the scientist but it provides him with the very vocabulary and sentence structure to express his discoveries. The scientist uses mathematics as more than a tool or template. The ideas he wishes to express become essentially mathematical and cannot be communicated except by the language of mathematics. This fact in itself, you say, is not thereby germane to problems of mathematics teaching in general education. Few of our boys and girls in our public schools will become scientists. I do not propose that mathematics instruction for all should be geared to the needs of the few. We must, however, recognize those needs since the development of our civilization depends very heavily on a relatively few. We have always been and will continue to be dependent upon the fact that many expect much

from those few. It is my purpose to convey a point of view as to the nature of mathematics. This point of view is essential if the teaching of mathematics, is to rise above the limitations fixed by the automatic response drill emphasis. This is important for all students whether they be in our elementary schools, the high schools, or in our colleges.

Mathematics has been referred to as the science of drawing necessary conclusions. This emphasis reflects the character of mathematical reasoning as a method of thinking rather than as a language for thought expression.

You have frequently found yourself in a discussion with a friend. Both of you are sure of your arguments but they lead to conflicting conclusions. If you are interested in resolving your difficulties, you will seek to identify the basic sources of your disagreement. This may bring to light a difference of interpretation in the meanings of basic terms used. Possibly the arguments presented are based on certain unrecognized assumptions which are in conflict. The process of quickly identifying these difficulties leads to productive discussion. It may not lead to agreement but it does lead to a clear understanding of the essential disagreement. Too often the furious banter of words tends only to confuse, not to clarify; to fix prejudices, not to encourage constructive analysis. We often follow the leadership of the clever word artist without realizing where it leads. I am reminded of an observation made by an observer of a session of Congress. He is reported to have commented that Congress is most peculiar. A man gets up to speak, says nothing, nobody listens, and then—everybody disagrees!

I ask you to consider with me a very quick glance at our mathematical past. Mathematics has had a long history in world civilizations. "Philosopher" or "mathematician" became one of the earliest classifications of scholars. Mathematics became one of the earliest classifications of subject matter to be formalized into systematic bodies of knowledge. Euclid, in the latter part of the fourth century before Christ had succeeded in building a logical structure from various geometric relationships which were known. The logical structure of Euclid's work was so extensive, complete and satisfying that Euclid's Elements became the basis of study in demonstrative plane geometry with little change for over 2000 years. As recently as fifty years ago, the subject was often known as "Euclid" rather than as "Geometry."

Only 325 years ago, scarcely more than four life spans, Galileo was severely censured, his physical freedom was restricted, and he was subjected to threats of torture because he disputed the view that the earth stood still at the center of the world and the sun

moved around the earth. Galileo was not successful in completely identifying the interdependence of force and motion but his writing paved the way for Newton, whose birth coincides with the year of Galileo's death. (It was said that Newton was unsuccessful with his books in school until his spirit of emulation was sparked by success in a fight with another boy and led to his becoming head of the school.)

Galileo's work is chacterized as a combination of experiment with calculation. He was interested in the telescope, the pendulum, and such apparatus. From the Leaning Tower of Pisa he performed the dramatic experiment to demonstrate that bodies of different weights fall with the same velocity. Newton obtained unanticipated results from calculations. His calculations led to the statement of the law of gravitation: that the mutual action of two masses of matter is a force drawing them together and varying directly as the product of their masses and inversely as the square of their distance apart. He invented the elements of differential calculus as an aid to carrying out calculations. He enunciated principles of mechanics which sent men of science to their laboratories in search for experimental evidence of the results of his computations.

During the last seventy-five years accelerated changes have been taking place in our scientific knowledge. The fall of the apple is subject not only to the force of attraction between it and the earth, but also to the force transmitted by virtue of the earth's rotation. Newton assumed the apple fell toward the center of the earth. Perhaps even the idea of gravity is an illusion. Newton's law of gravitation and the geometry of Euclid have given way to new hypotheses in the newer relativity theories. The test of a theory is in the consistency between its predictions and observable natural phenomena. The source of a theory is a combination of interpreting observed natural phenomena in nature and accepting the consequences of computation. The mathematician must develop new mathematics to interpret man's observations. The scientist must seek evidence to support or reject new predictions based on the conclusions of the new mathematical computations. It is by such processes that we have developed a knowledge of the atom which enables us to compute the energy latent therein and to take the first steps in releasing that energy for the purposes to which man gives precedence. It is by such processes that the pupils in our classrooms must equip themselves to meet the demands being made on their ability to solve increasingly complex problems and to think clearly.

It is not my purpose to impress you with the long and rich traditions of which the subject mathematics can boast. However, we *are* interested in the essential cultures of our civilization. We are in-

terested in developing individuals who are able to contribute to those cultures. Still more generally we are interested in developing individuals who are able to find personal satisfactions in the enduring aspects of their personal cultural and intellectual lives.

I have tried to paint a picture of rapid change in the realms of scientific knowledge. Like changes are taking place in the areas of personal and social life. We cannot mold the educational curriculum to teach merely those skills which are currently in use. We may survey the work of artisans in the community and observe the things people do. We must remember that our pupils are not preparing for life tomorrow to be lived as it is today. They are living a life today in preparation for an unknown one tomorrow. We cannot presume to know what problems our pupils will meet as adults. We know they meet problems today. We must examine our educational program in the light of those facts. Pupils will develop problem solving abilities only by meeting situations in which they sense problems and have a desire to solve them.

There are two handicaps which mathematics teachers must overcome if we are to make the most of our opportunities to make the study of mathematics a vital experience to large numbers of boys and girls. One is the psychology of protecting mathematics in its traditional forms as a time honoured requirement in educational programming. The other is the systematic logical unity of bodies of mathematical disciplines, skills, and techniques.

A major difficulty which you as educational managers as well as your mathematics teachers must meet springs primarily from a misconception of the nature of mathematics.

Much of our present day emphasis in mathematics instruction has developed during the past fifty years. The mathematics classroom lags far behind the pronouncements of its educational leaders and committee reports. This is not a situation at all peculiar to mathematics as a public school subject. The elementary schools have been more quickly subject to change than the secondary schools have been.

In 1901, John Perry in England expressed the belief that the teaching of demonstrative geometry and orthodox mathematics was destroying rather than developing desirable thinking abilities. He held that it was important to teach a student through his own experiments and observations of concrete examples worked out himself. In 1902, E. H. Moore in a presidential address before the American Mathematical Society suggested that pupils study things not words, that algebra, geometry, and physics be organized in a thoroughly coherent four year course, that pupils should obtain results of importance by several distinct methods, that the pupil in

learning should become independent of authority. Perry and Moore alike were evidencing impatience with the dependence on the formal and artificial forms of learning as illustrated for example by Euclid's Elements.

In order to enable teachers to make such breaks from the fetters of tradition, many have suggested less dependence on text books, greater use of community resources and many types of change in classroom method and curriculum reorganization. I have great confidence that in the hands of a master teacher with less than the normal teaching load that any one of a variety of such suggestions presents much promise. There is much merit in the idea that what experimental classroom procedures a teacher uses are not as important as the fact that she is using experimental procedures. There is, of course, always the problem the child meets of coordination with later steps on the educational ladder which definitely restricts the teacher's freedom.

There are two big problems which we face. The first is properly trained teachers with a thorough comprehension of their subject and of children and with a sound educational philosophy. The second is teacher time, opportunity, encouragement, and help for classroom research work. One of the most promising trends of recent years is the interest in summer workshop activities, in cooperative curriculum studies by classroom teachers in city and state school systems, and in the recognition that the teacher and pupil, rather than the course of study, are the essential elements in sound education.

I have long felt that a twelve month contract between teachers and their school boards might provide the basis of a desirable type of professional interest in teachers. It could make the difference between teachers whose school days are limited to school appointments and paper work and teachers who are actively engaged in constructive classroom research for more vital teaching.

The mere act of proving theorems in geometry, the mere evidence of facility in algebraic operations, the mere facility with numerical computations are not sufficient evidence of mathematical literacy. The schools should guarantee essential functional competence in mathematics to each pupil within the limits of his ability to develop such competencies. We must bestir ourselves from a sort of psychosis which grows out of emphasis on mathematics as a mere tool subject.

The personal and social aims of education must find greater emphasis in mathematics instruction, but above all we must learn to teach mathematics in a manner consistent with the way mathematics has developed. As a meaningful body of learning activities it must combine observation and computation. Neither can be first. It must

receive more emphasis as a method of expressing observed relationships, as a way of thinking, as a process of solving problems, and as a basis for determining courses of action.

For many authoritative suggestions, for blue prints of mathematical curricula and methods of instruction, I refer you to the First and Second Reports of the Commission on Post-War Plans of the National Council of Teachers of Mathematics. These reports were published in the May issues of the *Mathematics Teacher* for 1944 and 1945 respectively. The final report of this commission is Guidance Pamphlet in Mathematics for High School Students published in the *Mathematics Teacher*, November, 1947.

The problems of mathematical instruction cannot be solved by any one group alone. It is a process which requires the cooperation of the mathematician, the mathematical educationist, the classroom teacher, the general educationist, and by all means the educational administrator. We have been shown many substantial blue prints during the past fifty years. We must translate these into action, into the curricula and learning activities of our classrooms.

We must be guided by the fact that the problems boys and girls face and can recognize present the major opportunities for constructive learning properly conceived. We must also recognize that education is training for adjustment to future and unpredictable demands. We cannot assume, nor would we hope that the specific needs of today are to be those of tomorrow. We can feel security in our responsibilities only if we take every means to properly equip boys and girls to adjust to the changing world we and our forefathers have helped create. Change does not always mean progress. We know only that there is nothing more changeless than the fact of change.

HOUSE FAILURE IS COSTLY

The failure of the House to act favorably on federal-aid legislation during the last session means denial to millions of young people of a chance to mature into citizens qualified to shape the country's future.

What are some of the critical facts the House leadership has ignored?

Approximately four million children of school age are in no school.

An estimated 95,000 teachers hold substandard certificates.

The shortage of qualified teachers is staggering.

The prospect for an adequate supply in the foreseeable future is most discouraging.

More than eight million adults, over 25 years of age, have less than a fifth-grade education.

Were our country faced with a national emergency again, vast numbers of young men and women could not qualify for national service because of shortages in schooling.

In eight states, average annual salaries for teachers, 1948–49, was less than \$2000; in one state, less than \$1500.

NEA Journal

SECTION REPORTS OF THE CASMT NOVEMBER MEETING

Geography Section

The meeting was called to order by the chairman, Floy Hurlbut, at 2:40 P.M., on the North Terrace of the Edgewater Beach Hotel. Dr. S. M. McClure, the first speaker on the program was introduced and spoke very interestingly on the subject "Illinois Rocks and Minerals for the Earth Science Laboratory." He divided the state of Illinois into five collecting areas and described in some detail the various minerals available in each and how they should be prepared for laboratory use.

The report of the nominating committee was read and the following officers were elected.

Chairman	Miss Laura L. Watkins Lincoln School Cicero, Illinois
Vice-chairman	Miss Mabel Washburn Shortridge High School Indianapolis, Indiana
Secretary	Miss Ester Arthur South Shore High School Chicago, Illinois

The second speaker, Dr. Nathan Woodruff, Assistant Chief of the Isotopes Division, Atomic Energy Commission, Oak Ridge, Tennessee, was introduced. His paper, "Fissionable Earth Materials" was well received. He pointed out the two major elements used in producing atomic energy, and used maps to show their general distribution in the United States and the world. He also mentioned the fact that, in general, they occur in rather small quantities. His address was followed by a brief discussion.

The manuscripts of both papers will appear later in School Science and Mathematics.

Laura Louise Watkins

Physics Section

Mr. Leo J. Walton of Western High School, Detroit, Michigan, called the meeting to order in the Ball Room of the Edgewater Beach Hotel. He introduced the other officers of the section, Vice-Chairman, J. S. Richardson, Science Education, Ohio State University and Secretary Delia Redman of New Haven High School, New Haven, Indiana.

Sylvan Mikelson, University School, Ohio State University talked of and showed many new books as "Selected References for High School Physics," a revision of the list that Dr. J. P. Cahoon gave two years ago. Mikelson promised to send the list to the editor of School Science and Mathematics.

Eiffel Plasterer, Huntington, Indiana, whose demonstration with soap bubbles has made him famous, came out of retirement and gave a demonstration with pendulums that was as colorful and intriguing as his soap bubble one. His pendulums performed as had his soap bubbles. Things of beauty were the slides of drawings traced by stili attached to pendulums vibrating at the same time but in different periods.

Dr. Karl Lark-Horovitz, Purdue University, Lafayette, Indiana talked on Radioisotopes in Research. His introduction was an interesting one showing that the study of atomic energy is an old one. The United States Atomic Energy Commission slides that he used showed the two most generally used isotopes are of iodine and phosphorous and that these two are used almost wholly for medicine and animal physiology.

Dr. Lark-Horovitz explained the structure of a pile and pointed the way, now that isotopes can be safely and fairly cheaply prepared in a pile, for their use as a

modern means of chemical and physical analysis both in schools and in industry.

The chairman of the nominating committee presented the names of the following persons who were unanimously elected: Chairman, J. S. Richardson; Vice-chairman, Delia Redman; Secretary, S. Fred Calhoun.

DELIA REDMAN, *Secretary*

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve his readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the one submitted in the best form will be used.

Late Solutions

2134. *K. W. A. Smith, Kensington Gardens, South Australia.*

2161. *L. E. Jones, Woodstock, Conn.*

2164. *Hugo Brandt, Chicago; Orville A. George, Mason City, Iowa.*

2167. *Proposed by Philip Maclasky, Philadelphia.*

In any triangle, the mid-point of a side, the mid-point of the segment joining the vertex opposite this side to the point where the in-circle touches the side, and the in-center are collinear.

Solution by the proposer.

Given: Circle F tangent to the sides of triangle ABC at D, L, and K respectively. H bisects CD and E bisects AB.

To prove: H, F and E are collinear.

Let $AB=2c$, $AC=2b$ and $BC=2a$. Let the perimeter of triangle $ABC=4s$. Let the in-radius $=r$. Then

$$4s=2a+2b+2c$$

$$2s=a+n+c$$

and

$$a+b-c=2s-2c. \tag{1}$$

Let

$$GF=e \quad \text{and} \quad DE=f.$$

Then

$$MN=ND=e,\ NA \text{ extended meets } SC \text{ in } M.$$
$$AD=c-f$$

Now

$$AD=2s-2a$$

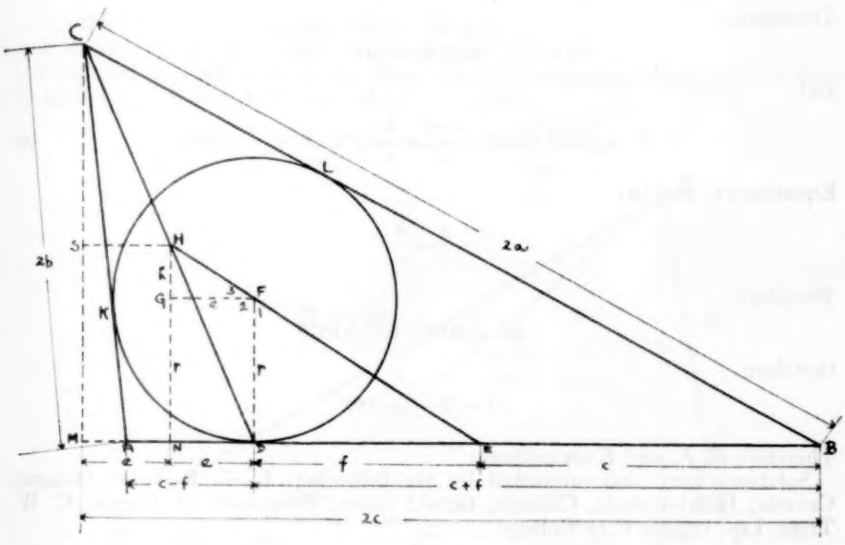
therefore

$$a+b+c-2a=c-$$

and

$$f=a-b \tag{2}$$
$$MC=2MS=2(h+r) \tag{3}$$

since H bisects CD



From right triangle AMC and right triangle BMC

$$\overline{AC}^2-\overline{AM}^2=\overline{MC}^2=\overline{BC}^2-\overline{BM}^2$$

or

$$4b^2-[2e-(c-f)]^2=4a^2-(c+f+2e)^2.$$

Simplifying

$$a^2-b^2=cf+2ce$$
$$(a-b)(a+b)=cf+2ce$$

From (2) we get

$$f(a+b)-cf=2ce$$

and

$$\frac{e}{f}=\frac{a+b-c}{2c}.$$

From (1)

$$\frac{e}{f}=\frac{2s-2c}{2c}$$

and

$$\frac{e}{f}=\frac{s-c}{c}. \tag{4}$$

$$\text{Area } \triangle ABC=\tfrac{1}{2}AB\cdot MC.$$

Using (3)

$$\text{Area } \triangle ABC=\tfrac{1}{2}\cdot 2c\cdot 2(h+r)$$

$$\text{Area } \triangle ABC=2c(h+r). \tag{5}$$

Also

$$\text{Area } \triangle ABC=2rs.$$

Therefore

$$2c(h+r)=2rs$$

and

$$\frac{s-c}{c}=\frac{h}{r}. \tag{6}$$

Equating (4) and (6)

$$\frac{e}{f}=\frac{h}{r}.$$

Therefore

$$\text{Rt. } \triangle DEF\sim\text{Rt. } \triangle HGF$$

therefore

$$\angle 1+\angle 2+\angle 3=180°.$$

Therefore H, F, and E are collinear.

Solutions were also submitted by the following: E. C. Rodway, Ontario, Canada; Hugo Brandt, Chicago; Gerald Sabin, University of Tampa; C. W. Trigg, Los Angeles City College.

2168. *Proposed by V. C. Bailey, Evansville, Indiana.*

In triangle ABC, if $c=b+\frac{1}{2}a$, and BC is divided at D so that $BD:DC::1:3$, prove that $\angle ACD=2\angle ADC$.

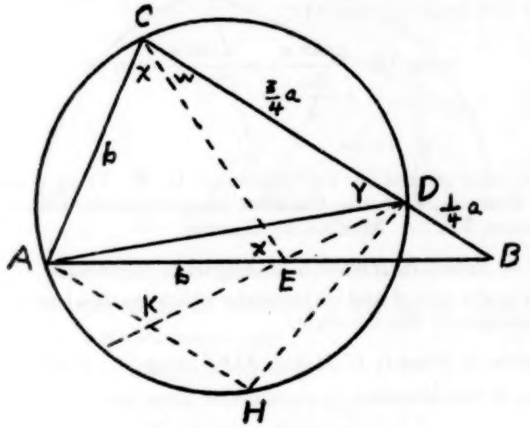
Solution 1 by W. J. Cherry, Berwyn, Ill.

On AB lay off $AE=b$. Then $EB=\frac{1}{2}a$. Circumscribe a circle about triangle ADC. With D as center and b as a radius strike an arc cutting the circle at H. Draw line segments AD, AH, HD, and CE. Produce DE to intersect AH at K. Denote $\angle ACE$ by x, $\angle AEC$ by x, $\angle ECD$ by w, and $\angle ADC$ by y.

Now two sides of triangle CEB are proportional to two sides of triangle BDE and $\angle B$ is included between these sides. Hence the triangles are similar. It follows that $CE=2DE$, $\angle DEB=w$, and $\angle CDE=x$.

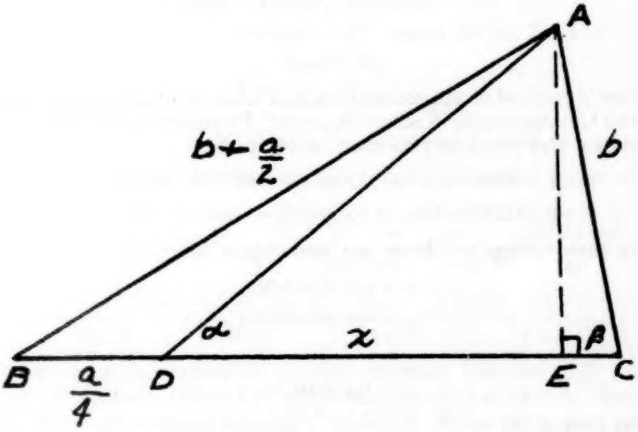
$\angle DAH$ is measured by half the arc subtended by $HD=b$ and hence is equal

to y. Using known angles we easily get $\angle AEK = w$, $\angle KDH = w$, $\angle DKH = x$, $\angle AKD = 180° - x$, and $\angle EDB = 180° - x$.



$\triangle AKE$ is similar to $\triangle EBD$. Hence $AK = \frac{1}{2}b$.
$\triangle KHD$ is similar to $\triangle DEC$. Hence $KH = \frac{1}{2}\ HD = \frac{1}{2}b$.
Then $AH = b$, and $\angle ADH = y$. Observing the intercepted arcs, we see that $\angle ADH + \angle DAH = \angle ACD$; or $\angle ACD = 2\angle ADC$.

Solution 2 by Max Beberman, Shanks Village, N. Y.



Let $x = DE$ and draw $AE \perp BC$ at E.
Then from right triangle AEB we have

$$\left(x+\frac{a}{4}\right)^2 = \left(b+\frac{a}{2}\right)^2 - b^2(1-\cos^2\beta) \tag{1}$$

where $\beta = \angle ACD$ and $\alpha = \angle ADC$. But in right triangle AEC,

$$b\cos\beta = \frac{3a}{4} = x. \tag{2}$$

Solving (1) and (2) for x we have

$$x = (3a+4b)/8. \tag{3}$$

Now from trigonometry, we have identically

$$\tan \beta/2 = \sin \beta/1+\cos \beta. \tag{4}$$

From the figure and from (2) and (4):

$$\tan \beta/2 = \frac{x \tan \alpha}{b+\frac{3a}{4}-x} = \frac{x \tan \alpha}{2x-x} = \tan \alpha \tag{5}$$

$$\therefore \quad \beta = 2\alpha.$$

Solutions were also offered by the following: C. W. Trigg, Los Angeles City College; E. C. Rodway, Ontario, Canada; Hugo Brandt, Chicago; Dwight L. Foster, Tallahassee, Fla.; A. MacNeish, Chicago.

2169. *Proposed by Robert E. Horton, Los Angeles, California.*

Given the circle $x^2+y^2=a^2$ and its involute which starts at point $(a, 0)$. Locate the x and y intercepts of the involute.

Solution by Francis L. Miksa, 613 Spring St., Aurora Ill.

The equations of the involute, in parametric form are:

$$x = a \cos \theta + a\theta \sin \theta \tag{1}$$

$$y = a \sin \theta - a\theta \cos \theta. \tag{2}$$

To find the y intercepts we equate (1) to zero, and solve for angle θ. This substituted in (2) will give the y intercept. For x intercepts we reverse the procedure, solve (2) for $x=0$ and substitute in $b1$). Thus:

$$a \cos \theta + a\theta \sin \theta = 0 \tag{3}$$

or

$$\cot \theta = -\theta. \tag{4}$$

Using Newton's method of approximation and table of "Circular and Hyperbolic Tangents and Cotangents for Radian Measure" Prepared by the National Bureau of Standards we find the first two roots of (4) to be:

$$\theta_1 = 2.7983861 = (\pi - 0.3432066) = (180° - 19.664290°)$$

$$\theta_2 = 6.1212505 = (2\pi - 0.16193484) = (360° - 9.2781829°).$$

Substituting these values in (2) we get two values of y

$$y_1 = +2.9716939a$$

$$y_2 = -6.20239531a$$

equating (2) to zero we get:

$$\tan \theta = \theta. \tag{5}$$

The smallest root of (5) is

$$\theta_3 = 4.49344095 = (\pi + 1.3518168) = (180° + 77.453397°).$$

Whence

$$x_1 = -4.6033695a.$$

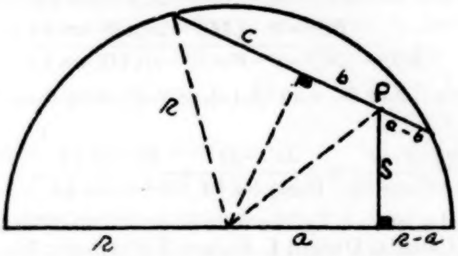
Of course the number of x and y intercepts is unlimited depending on the angle θ. The above however gives the intercepts for $\theta < 360°$.

Solution also offered by: Hugo Brandt, Chicago.

2170. *Proposed by C. W. Trigg, Los Angeles City College.*

The square of the perpendicular dropped from a point on a chord of a semicircle to the diameter equals the product of the segments of the diameter less the

product of the segments of the chord.



*Solution by **Max Beberman, Shanks Village, N. Y.***

After the three constructions, as indicated in the figure, we have

$$s^2+a^2=b^2+(r^2-c^2)$$
$$s^2=r^2-a^2-(c^2-b^2)$$

or

$$s^2=(r+a)(r-a)-(c+b)(c-a).$$

Other solutions were also offered by the following: David Rappaport, Chicago; W. J. Cherry, Berwyn, Ill.; Hugo Brandt, Chicago; Gerald Sabin, University of Tampa; Margaret Joseph, Milwaukee, Wis.; A. MacNeish, Chicago; Dwight L. Foster, Tallahassee, Fla.; and the proposer.

2171. *Proposed by Ruth Poultius, Mobile, Alabama.*

If the bisector of angle A, of triangle ABC, meets BC at D, show that

$$AD=\frac{2bc}{b+c}\cos\frac{A}{2}.$$

Solution by C. W. Trigg, Los Angeles City College.

Method I. From the well-known formula for the internal bisector of an angle of a triangle,

$$AD=\sqrt{bc-(BD)(DC)}=\sqrt{bc-\frac{ac}{b+c}\cdot\frac{ab}{b+c}}=\frac{bc}{b+c}\sqrt{\frac{(b+c)^2-a^2}{bc}}$$
$$=\frac{2bc}{b+c}\sqrt{\frac{(b+c+a)(b+c-a)}{4bc}}=\frac{2bc}{b+c}\sqrt{\frac{s(s-a)}{bc}}=\frac{2bc}{b+c}\cos\frac{A}{2}.$$

This result may be extended to the external bisector AD', since $BD'=ac/(b-c)$ whereupon $DD'=BD'+BD=ac/(b-c)+ac/(b+c)=2abc/(b^2-c^2)$. Now ADD' is a right triangle so $(AD')^2=(DD')^2$. When the values of DD' and AD are substituted in this equality and the result is simplified, we have finally

$$AD'=\frac{2bc}{b-c}\sin\frac{A}{2}.$$

Method II. From Stewart's Theorem,

$$a(AD)^2=b^2(BD)+c^2(CD)-a(BD)(CD)=\frac{acb^2}{b+c}+\frac{abc^2}{b+c}-\frac{a^3bc}{(b+c)^2}.$$

Then

$$AD=\sqrt{bc-\frac{a^2bc}{(b+c)^2}}=\frac{2bc}{b+c}\sqrt{\frac{(b+c)^2-a^2}{4bc}}=\frac{2bc}{b+c}\sqrt{\frac{s(s-a)}{bc}}=\frac{2bc}{b+c}\cos\frac{A}{2}.$$

Method III. From the law of cosines,

$$\begin{array}{r} (BD)^2=c^2+(AD)^2-2c(AD)\cos\tfrac{1}{2}A \\ (DC)^2=b^2+(AD)^2-2b(AD)\cos\tfrac{1}{2}A \\ \hline (BD)^2-(DC)^2=c^2-b^2+2(b-c)(AD)\cos\tfrac{1}{2}A \end{array}.$$

Now $BD=ac/(b+c)$ and $DC=ab/(b+c)$. Substituting these values and simplifying, we have

$$AD=\frac{(b+c)^2-a^2}{2(b+c)\cos\frac{1}{2}A}=\frac{2s(s-a)}{(b+c)\cos\frac{1}{2}A}=\frac{2bc\cos^2\frac{1}{2}A}{(b+c)\cos\frac{1}{2}A}=\frac{2bc\cos\frac{1}{2}A}{b+c}.$$

Solutions were also offered by the following: A. MacNeish, Chicago; E. C. Rodway, Ontario, Canada; Dwight L. Foster, Tallahassee, Fla.; Max Beberman, Shanks Village, N. Y.; Francis L. Miksa, Aurora, Ill.; W. J. Cherry, Berwyn, Ill.; Hugo Brandt, Chicago; C. S. Carlson, Northfield, Minnesota; David Rappaport, Chicago.

2172. *Proposed by Clara Lane, Chevy Chase, Md.*

In any plane triangle ABC, if $\tan\frac{1}{2}A=5/6$ and $\tan\frac{1}{2}B=20/37$ show that $a+c=2b$.

Solution by C. W. Trigg, Los Angeles City College

Consider the general case where $\tan\frac{1}{2}A=x$ and $\tan\frac{1}{2}B=y$. Then

$$\tan\tfrac{1}{2}C=\cot(90°-\tfrac{1}{2}C)=\cot(\tfrac{1}{2}A+\tfrac{1}{2}B)=(1-xy)/(x+y).$$

Now

$$\tan\tfrac{1}{2}A=r/(s-a)=2r/(b+c-a)=x,$$
$$\tan\tfrac{1}{2}B=r/(s-b)=2r/(c+a-b)=y,$$

and

$$\tan\tfrac{1}{2}C=r/(s-c)=2r/(a+b-c)=(1-xy)/(x+y).$$

Solving these equations simultaneously, we have

$$a=bx(y^2+1)/y(x^2+1),\qquad c=b(x+y)(1-xy)/y(x^2+1)$$

so

$$a+c=b(2x+y-x^2y)/y(x^2+1).$$

If, as in this proposal, $x=5/6$ and $y=20/37$ then $a+c=2b$.

NOTE BY EDITOR: This problem was not correctly printed, the "$2b$" being 26. Max Beberman, Shanks Village, N. Y. discovered the error and sent in a solution.

HIGH SCHOOL HONOR ROLL

The editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

2170. *Richard Schubert, J. Sterling Morton H. S., Cicero, Ill.*

2168, 70, 71. *Mathematic Club (Pythagorean), Hyde Park H. S., Chicago.*

2170. *Clyde Lindner, Red Bank H. S., Red Bank, N. J.*

PROBLEMS FOR SOLUTION

2185. *Proposed by Warren E. Shingle, Houghton, N. Y.*

In a parallelogram $ABCD$, an arbitrary line through A cuts BD at E, BC at F and DC at G, prove $1/AE=1/AF+1/AG$.

2186. *Proposed by Adrian Struyk, Paterson, N. J.*

Using four fours in conjunction with decimal, radical and factorial notation,

(a) Express as many positive integers as possible in the form $a+b/(a-b)$. Example

$$2=(\sqrt{4}+\sqrt{.\dot{4}})/(\sqrt{4}-\sqrt{.\dot{4}}) \quad \text{or} \quad \frac{\sqrt{4}+\sqrt{.\dot{4}}}{\sqrt{4}-\sqrt{.\dot{4}}}.$$

(b) Discover a relation having the form:

$$(a+4)/(a-4)=(4+b)/(4-b)=(\sqrt{a}+\sqrt{b})/(\sqrt{a}-\sqrt{b}).$$

2187. *Proposed by Adrian Struyk, Paterson, N. J.*

A quadrilateral $ABCD$ has sides, whose lengths are the roots of the equation:

$$(x^2-2mx+p^2)(x^2-2nx+q^2)=0$$

where $m^2-n^2=p^2-q^2$. Find the area of $ABCD$.

2188. *Proposed by Howard D. Groseman, N. Y.*

What is the probability that three or more children in a family of eight children have the same birthday?

2189. *Proposed by Norman Anning.*

Prove the identity: $\sin p \sin q+\sin r \sin (p+q+r)\equiv\sin (p+r) \sin (q+r)$.

2190. *Proposed by Adrian Struyk, Paterson, N. J.*

In triangle ABC, CH is the altitude to AB, and $\angle C=45°$. It is required that the altitudes AH, BH, and CH, have integral lengths. Without use of trigonometry show how to determine integral lengths.

BOOKS AND PAMPHLETS RECEIVED

Introduction to the Theory of Probability and Statistics, by Niels Arley, *Assistant Professor of Physics, Institute for Theoretical Physics, University of Copenhagen*, and K. Rander Buch, *Assistant Professor of Mathematics, Institute for Applied Mathematics, Denmark Institute of Technology.* Cloth. Pages xi+236. 14.5×23 cm. 1950. John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. Price $4.00.

College Algebra, by Earle B. Miller, *Professor of Mathematics, Illinois College*, and Robert M. Thrall, *Associate Professor of Mathematics, University of Michigan.* Cloth. Pages xvii+493. 13.5×20.5 cm. 1950. The Ronald Press Company, 15 E. 26th Street, New York 10, N. Y. Price $3.75.

Measuring Our Universe, by Oliver Justin Lee, *Professor of Astronomy and Director, Emeritus, Dearborn Observatory, Northwestern University.* Cloth. Pages x+170. 14×21.5 cm. 1950. The Ronald Press Company, 15 E. 26th Street, New York 10, N. Y. Price $3.00.

Numbers We See, by Anita Riess, Maurice L. Hartung, and Catharine Mahoney. First-Grade Number-Readiness Book. Teacher's Edition. 162 pages with sample Oaktag Window and Frame. Cloth. 19.5×25.5 cm. 1948. Scott, Foresman and Company, Chicago 11, Ill. Price $1.32.

Arithmetic Readiness Cards, Set 1: Grouping, by Maurice L. Hartung, Henry Van Engen, and Helen Palmer. 54 Picture Cards, 16.5×21.5 cm. with Pictures on both Sides in Four-Color, each Card Slotted for Insertion of Corresponding Number Cutout. Set of 54 Cards comes Boxed, with 9 Sheets of Num-

ber Cutouts and a 12-page Teacher's Guidebook. 1949. Scott, Foresman and Company, Chicago 11, Ill. Price $3.20.

TRILINEAR CHART OF NUCLEAR SPECIES, by William H. Sullivan, *Scientific Director, Naval Radiological Defense Laboratory, San Francisco 24, California.* Art Work by Kay Benscoter. 21×27 cm. 1949. John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. Price $2.50.

INSTRUCTIONAL TESTS IN PLANE GEOMETRY, by Florence C. Bishop, *Chairman Mathematics Department, Central High School, Flint, Michigan,* and Manley E. Irwin, *Supervising Director of Instruction, Public Schools, Detroit, Michigan.* Revised Edition. Paper. Pages x+68. 16×25.5 cm. 1950. World Book Company, Yonkers-on-Hudson, New York.

SQUARED CIRCLES AND SPHERES, CUBED SPHERES, CONVERSIONS AND EQUIVALENTS, by Charles Cressey, *Architect.* Paper. 26 pages. 15.5×23.5 cm. 1949. Charles Cressey, 2135-28th Avenue, San Francisco 16, Calif. Price $1.50 plus 3% tax in Calif.

SCHOOL IN THE HOSPITAL, by Romaine P. Mackie, *Specialist for Schools for the Physically Handicapped,* and Margaret Fitzgerald, *Principal Teacher in Charge of Education of Patients, Grasslands Hospital, Valhalla, New York.* Pages vi+54. 15×23.5 cm. Bulletin 1949. No. 3. Superintendent of Documents, United States Government Printing Office, Washington 25, D. C. Price 20 cents.

WHAT TEACHERS SAY ABOUT CLASS SIZE, by Ellsworth Tompkins, *Specialist for Large High Schools.* Circular No. 311. Pages vi+45. 20×26 cm. 1949. Superintendent of Documents, United States Government Printing Office, Washington 25, D. C. Price 20 cents.

BOOK REVIEWS

HYDROLOGY. PHYSICS OF THE EARTH—IX, Edited by Oscar E. Meinzer. Published under the Auspices of the National Research Council. Cloth. Pages xi+712. 15×23.5 cm. 1942. Dover Publications, Inc., 1780 Broadway, New York 19, N. Y. Price $4.95.

This is one of the most comprehensive books ever presented on this subject. One look at the list of contributors shows its value to geologists, physicists, civil and sanitary engineers, teachers, and all others interested in the broadening field of this branch of science. The depletion of the water supply and its effects on many of the great cities from Los Angeles to New York City and much of the farm land between has brought the subject of hydrology to the front in the field of science. The fifteen chapters which make up this text were written by twenty-five experts, including the editor who is also the author of Chapter 1. Each chapter closes with a long list of references covering the topics under discussion, published in the leading journals and books in all languages. Excellent photographs, maps, and graphs illustrate the book and aid in the explanations and descriptions. Some of the chapters were written by one man, as the chapter on Glaciers by Francis E. Matthes, but the list of references includes 104 books and articles from the great journals of many countries. The next chapter on Lakes by Professor Sidney T. Harding of the University of California is a short chapter but one that contains much of interest and value to all. Chapter XI, "Runoff," contains nine major divisions written by seven of the nation's experts, and is the longest chapter. The book will not only interest college professors and engineers but will be valuable to all city dwellers, farmers, and land owners everywhere because it covers such important topics as soil moisture, flood control, water table fluctuations, erosion, water storage, and natural distribution of water in the

atmosphere, on the surface, and underground. No public or school library should be without this book.

G. W. W.

YOU CAN'T WIN: FACTS AND FALLACIES ABOUT GAMBLING, by Ernest E. Blanche Ph.D., Author of Off to the Races, The Mathematics of Gambling. Cloth. 155 pages. 12.5×19.5 cm. 1949. Public Affairs Press, 2153 Florida Avenue, Washington 8, D. C. Price $2.00.

This little book should be read by millions of people who will never take time to look at it. Throughout the ages people have been ready to risk small savings or large fortunes on various types of gambling—dice, races, cards, punch boards, and carnival wheels. Nearly all are losers of whom we seldom hear. Once in millions some one draws a lucky ticket and wins thousands on the Irish Sweepstakes. Then every newspaper is filled with it. The author's regular work has nothing to do with any of this, but he has been a student of the techniques of gambling for many years, studying under great mathematicians such as the late Prof. A. R. Crathorne and Prof. C. H. Richardson. He gives here many of the tricks, extending all the way through, from the penny gambling boards set up to entertain children and collect their pennies, through the bingo games going on in the church basements and in your own homes, on through the dice and poker dens to the great horse races at all the famous tracks. ". . . it is significant that, with the exception of only one state, Nevada, and only a few gaming enterprises, gambling is not permitted by law throughout the country. It is common knowledge that the 'fine art of gaming' flourishes in every city and hamlet from coast to coast, insidiously encompassing an increasing number of men, women, and even children." The facts given in this book should be known by everyone. Of course there will always be plenty of numbskulls who believe in luck and will dispose of their cash.

G. W. W.

MATHEMATICS DICTIONARY, by Armen A. Alchian, *University of California at Los Angeles;* Edwin F. Beckenbach, *University of California at Los Angeles;* Clifford Bell, *University of California at Los Angeles;* Homer V. Craig, *University of Texas;* Glenn James, *University of California at Los Angeles;* Robert C. James, *University of California at Berkeley;* Aristotle D. Michal, *California Institute of Technology;* Ivan S. Sokolnikoff, *University of California at Los Angeles.* Edited by Glenn James and Robert C. James. Cloth. Pages v+432. 16×23.5 cm. D. Van Nostrand Company, Inc., New York, N. Y. Price $7.50. 1949.

This revised and enlarge edition contains essentially all of the definitions which appeared in the two editions of the *James Mathematics Dictionary.* To that set of definitions, which provided a reasonably adequate coverage of terms through the calculus, has been added a group of terms likely to be encountered in more advanced work, such as matrix theory, topology, advanced calculus and differential equations, function theory; in addition, a rather extensive set of definitions of statistical terms has been added. As might be expected, the additional material is in general defined from a much more mature point of view. It would seem that possibly more time was devoted to adding new definitions than to the revision of existing definitions. In some cases, the student may encounter terms at the same level of his work, yet find the definitions written on radically different levels of maturity.

In a dictionary of this type, two considerations seem pre-eminent: completeness, and accuracy of definition. Many teachers might prefer to have the fields of college and projective geometry more thoroughly covered, but the authors make no claim to cover this field. In other fields, the following omissions might be noted: vortex, generating function, flat point, ring, zero matrix, cogredient, positive form. No doubt any user will find additional terms omitted which he would like to have defined—on the other hand, there is nothing available which even

approaches this dictionary from the point of view of completeness. With respect to the question of accuracy, it is again true that individual users may object to some of the definitions. For example, the reviewer does not agree that an *ascending power series* is the same as a *power series;* there is objection to a definition of *central conics* which apparently excludes circles and intersecting lines; the statement "the significant digits in 230 are 2, 3, and 0" is debatable with respect to the zero; the definition of *mode* would seem to exclude the possibility of a bimodal distribution. It must be emphasized that these form a very minor portion of the definitions; in general the standard of accuracy is extremely high. In fact, at some points a more serious objection would be that the definition, while accurate, might mean little to a student first encountering the term—example, the definitions of partial and multiple correlation.

The appendix contains a short set of numerical tables, a fairly complete short table of integrals, and an excellent listing of mathematical symbols. The book as a whole is a very marked improvement over the earlier editions. It is alomst imperative that every high school and college library should have at least one copy; it would be a valuable addition to any teacher's private library. In fact, any minor criticisms which may have been pointed out in this review are more than offset by the general value of the book; its high standard might be expected from the reputation of those who have contributed definitions.

CECIL B. READ
University of Wichita

CALCULUS, by Lyman M. Kells, *Professor of Mathematics, United States Naval Academy*. Second Edition. Cloth. Pages xii+508. 15.5×23 cm. 1949. Prentice-Hall, Inc., 70 Fifth Avenue, New York, N. Y. Price $4.00.

This text follows the current practice of the early introduction of integration. The current revision has some radical changes in the order of presentation of topics, and in particular introduces a chapter on vectors. This chapter covers more material than is usual in an elementary calculus text.

There is an ample supply of problems, more difficult exercises are marked. Answers are given to most of the problems, in fact more answers are provided than some teachers may wish. A few somewhat unusual features are: treatment of points of inflection before maximum and minimum points; derivation of the formula for a quotient from that for the derivative of a product, rather than direct use of the delta process; clearly stated rules, or methods of procedure, for handling certain topics.

Certain portions of the text might be improved: the figure on page 10 lacks complete explanation (if the line marked D is intended to be epsilon, the figure is incorrect); in the treatment of Newton's method nothing shows that the method is not valid for all first approximations to a root; in discussing the method of undetermined coefficients in solving linear differential equations it would not have taken much more space to state in what cases the method fails; the handling of significant figures is not always good (in the illustrative example on page 226 a number 399.280 is rounded to 400, yet using this rounded value a later result is expressed to four significant digits).

The text should definitely be considered when selecting a text for a first year course.

CECIL B. READ

LIVING MATHEMATICS, by Ralph S. Underwood, *Professor of Mathematics, Texas Technological College;* and Fred W. Sparks, *Professor of Mathematics, Texas Technological College.* 2nd edition. Cloth. Pages x+374; 16×23.5 cm. 1949. McGraw-Hill Book Co. Inc., 330 West 42nd Street, New York 18, N. Y. Price $3.00.

This is the second edition of a text planned for the nonspecialist, yet containing a considerable amount of the traditional subject matter. It is written with a cer-

tain "breezy" style which some will like but which others will find distasteful. The scope of mathematics covered is quite broad: some historical material; a considerable amount of algebra; some elementary mathematics of investment; trigonometry (solution of the oblique triangle restricted to use of laws of sines and cosines); analytic geometry; elementary calculus; generalized co-ordinate systems; a small amount of elementary number theory.

Some features seem exceptionally valuable for this type of course, for example: the derivation of the law of signs in multiplication; repeated emphasis on meaning rather than on formal manipulation; glimpses of the possibility of extension of the subject matter in many places.

In spite of the fact that the authors call the readers' attention to the need for rigor (as in the foot note on page 276), they are sometimes careless. In defining the rules of exponents they omit the restriction that the base must not be zero in certain cases; their definition of significant digits implies that 56,700,000 has eight significant digits.

Some teachers object to the use of different scales on the two axes when plotting the curve $y = \sin x$. An unfortunate spacing of the lines places the numbers .333 on one line and . . . on the succeeding line (p. 11). Certainly .333 . . . on one line would be preferable.

There is a reasonably large number of exercises with answers provided to the large majority; some teachers would prefer a larger supply of exercises without answers.

CECIL B. READ

HIGHER ALGEBRA FOR THE UNDERGRADUATE, by Marie J. Weiss, *Professor of Mathematics, Newcomb College, Tulane University.* Cloth. Pages viii+165. 14.5×22 cm. 1949. John Wiley and Sons, Inc., New York 16, N. Y. Price $3.75.

This text is planned for college juniors or seniors who have completed a course in the calculus. For such students there is sufficient material to provide six semester hours of work; it would also be possible to use the text on the graduate level, progressing more rapidly. Whether or not the book will fit the needs of a particular teacher and course can probably be determined only after examination. However, some idea of the content may be obtained from the chapter headings: The Integers; The Rational, Real, and Complex Numbers; Elementary Theory of Groups; Rings, Integral Domains, and Fields; Polynomials over a Field; Matrices over a Field; Determinants and Matrices; Groups, Rings, and Ideals.

Most students will find this book much easier reading than most of the standard textbooks in higher algebra; in fact, this could more nearly be studied without a teacher than most texts. It would provide valuable supplementary material for any course in higher algebra, irrespective of the text used. College teachers might well consider a course based on this text as an alternative for the traditional theory of equations course; material common to both courses would include DeMoivre's theorem, primitive *n*th roots of unity, relation between roots and coefficients of an equation, expansion of determinants, Cramer's rule, to mention only a portion. On the other hand, this text covers considerable of the material of elementary modern algebra which would not be given in a course in theory of equations.

Exercises are provided so that the student can be required to work exercises for each class meeting. Answers are not provided. Some teachers would prefer a longer list of exercises in order to provide alternate assignments. Any instructor desiring a text for a course of this nature would make a serious mistake by not considering this well written book.

CECIL B. READ

ANALYTIC GEOMETRY, by John J. Corliss and Irwin K. Feinstein, *University of Illinois, Chicago Undergraduate Division,* and Howard S. Levin, *The Glenn L. Martin Company.* Cloth. Pages xiv+370. 14.5×21.5 cm. 1949. Harper and Brothers, 49 East 33rd St., New York 16, N. Y. Price $3.25.

The publishers state: We are convinced that this book . . . provides a better analytic geometry book than has been available before . . . . The text is highly accurate . . . no incorrectly stated problems, . . . nor incorrect solutions. These are broad claims; how well they are met will depend in part on the viewpoint of the individual teacher. The book is definitely more comprehensive than most current texts; many teachers will fail to agree with the implications in the preface that the material can be covered in a seventy-five-hour course. As illustrative of material not usually found one might mention harmonic division, the principle of duality, rotation of oblique axes, many more construction problems than usual (example: construction of an ellipse given a pair of conjugage diameters).

Polar coordinates are introduced about half way through the text, and in general treated in separate sections. The treatment does not make it clear that the tests for symmetry given are sufficient, but not necessary. Tangents to curves are treated by the four-step rule of beginning calculus. Direction cosines and direction numbers are introduced with the treatment of the line in the plane, as well as parametric and symmetric forms of the equation, perhaps aiding the treatment of space geometry. An unusual notation is the use of double parentheses to indicate direction cosines or direction numbers.

The typography is in general excellent; unfortunately in some cases the figure for a theorem is so located that a student must turn the page to follow the discussion (examples: figures 26, 55, 64); a poor arrangement of footnotes is found on pages 87–8. A memory aid to the student which the reviewer has not seen elsewhere is found on page 18. Exercises seem ample in number; answers are provided to approximately half of these.

CECIL B. READ

COLLEGE ALGEBRA, THIRD EDITION, by Joseph B. Rosenbach, *Professor of Mathematics and Assistant Head of the Department*, and Edwin A. Whitman, *Associate Professor of Mathematics, Carnegie Institute of Technology*. Cloth. Pages x+523+xlii. 15×21 cm. 1949. Ginn and Company, Boston, Mass. Price $3.00.

After several years of reviewing elementary texts which seem to have an unnecessary lack of rigor, it is indeed a pleasure to find a book which is distinctly superior in this respect. The authors are very careful to stress necessary restrictions, for example, in defining negative (and zero) exponents it is pointed out that the base must not be zero. Again, in defining the meaning of the base a affected by the fractional exponent p/q, the restriction is imposed that if q is an even integer, a must be positive (moreover, the student is shown by an illustration *why* such restriction is needed). The definition of the mantissa of a logarithm is given in such a way that there is no ambiguity of meaning. In many cases, where proofs are beyond the scope of the text, the student is given more than one reference to a source where a proof may be found.

There are a large number of *Historical Notes* throughout the text, many of which should stimulate the student to do additional reading. Another very valuable feature is the many *Warnings* intended to illustrate common errors and help the student to avoid these errors (some teachers object to the practice of putting such material in print on the grounds that the student may be more impressed by the wrong method than by the correct one).

A very large supply of problems is available, with answers provided in the text to the odd-numbered exercises; answers are available in a separate pamphlet to all exercises (again some instructors object to such pamphlets being in print—the objection being that such material soon finds its way into students' hands even against the wishes of the instructor). The authors state that with the exception of some problems having historical interest and some more difficult statement problems, the problems in this edition are generally new.

If there be any objections to the text, it is probably from the point of view that more material is included than could be used in most courses. Another objection might be the inclusion of a small amount of material considered by many authori-

ties to be obsolete, i.e., nests of parentheses, including use of the vinculum (page 17); eleven cases of special products to be memorized (page 28); extremely complex problems involving exponents or radicals (pages 62–63, 71). However, the amount of such material is relatively small, and can be omitted if desired. As is the case with most texts, all the exercises in mathematical induction are true statements; it might be valuable to include some examples which challenge the student to determine their truth or falsity—some in which Part I of the proof cannot be shown, others in which Part II cannot be demonstrated. Again, following common practice, the student is given the logarithms, to the base 10, of 2, 3, and 7 and is asked to find the logarithm of such numbers as 42, 63, or 135/32. Many students work such problems by use of a table, rather than by use of the given logarithms. If the given logarithms were to the base 8, or, in fact, any base but 10, the student would find a table of little value.

Tables bound with the text include powers, roots, and reciprocals; common and natural logarithms to four decimal places; trigonometric functions; tables for interest and annuities; commissioners standard ordinary mortality table; factorials and their logarithms; and logarithms of certain mathematical constants.

Anyone contemplating a change of text should certainly consider this work which has had the advantage of trial in two previous editions.

CECIL B. READ

ARITHMETIC FOR TEACHER-TRAINING CLASSES, by E. H. Taylor and C. N. Mills. Cloth. Pages vi+441. 1949. Henry Holt and Company, New York, N. Y. Price $3.00.

This is the third edition of a text in arithmetic for teacher training. The plan of the book is first to teach the subject matter not as a review but with a new view of the subject, a teacher's view that insures mastery of the processes and a clear perception of difficulties, that unifies subject matter, and that furnishes some historical knowledge of its development. The methods used in presentation are those that the student can use later with his pupils. The complete range of topics in arithmetic are covered in this manner from addition and subtraction of integers, through fractions, percents, denominate numbers, to social topics such as banking and investments. The newer topics that have been introduced into the seventh and eighth grades in recent years are discussed. These include consumer credit, computation with approximate numbers, and an introduction to algebra and geometry. At the end of each topic numerous practice exercises are provided for the student as a means of his increasing his own understanding and proficiency.

Throughout the explanations and problem materials the authors emphasize the modern philosophy in teaching arithmetic, namely teaching for meaning, the importance of the pupils, deriving generalizations from concrete experiences, and seeing arithmetic as a system of ideas, facts, and principles. They also stress problem solving as a major objective and give help and practice with procedures.

Both authors are highly competent in the field. Their choice of materials and their presentations are the result of years of experience in training teachers of arithmetic. Their text deserves careful consideration from any teacher looking for a book of this type.

G. E. Hawkins
La Grange, Illinois

COLLEGE ALGEBRA, by Lewis M. Reagan, *University of Wichita;* Ellis R. Ott, *Rutgers University;* Daniel T. Sigley, *The Johns Hopkins University.* Cloth Pages xiii+447. 1948. Rinehart and Company, New York, N. Y. Price $4.00.

This is a revision of the 1940 edition of the text by the same authors and is intended for use in a standard course in college algebra. The trpics covered are those usually included in conventional texts. The authors state that the text is distinctive in three respects: (1) an emphasis upon the reasoning inherent in the various processes that are treated; (2) an inductive approach to new material;

and (3) the inclusion of new topics interwoven with a discussion of refresher topics. In an attempt to arouse and hold student interest numerous new topics are introduced in the first half of the book in conjunction with the review of former courses. One chapter is devoted to topics in statistics and one to the mathematics of finance. Practice exercises and problems are ample, and answers to about half of these are furnished in the text proper, immediately following the exercise. The text has sufficient material for either a three-hour or a five-hour course. Instructors looking for a new text will find this one worthy of their careful examination.

G. E. HAWKINS

ATLAS OF DRAWINGS FOR CHORDATE ANATOMY, by Samuel Eddy, *Professor of Zoology, University of Minnesota.* Paper. Pages xi+189 drawings. 1949. John Wiley & Sons Inc., New York, N. Y. Price $3.50.

This book is descriptively titled. It contains one hundred and eighty-nine unlabeled drawings of animals commonly used for study in college anatomy courses. It ranges through the entire Phylum Chordata. The drawings—excluding those on Amphioxus, *Molgula*, and Ammocoetes—are arranged primarily according to systems: integumental system, vertebral column and median fins, appendicular skeleton, skull and visceral skeleton, muscular system, general viscera, circulatory system, urogenital system, nervous system, and sensory organs. The principal animals used are the dogfish shark, *Necturus*, turtle, pigeon, and cat. Also included for some systems are the gar, bowfin, perch, alligator, and an amphibian.

It is the author's belief that outline drawings save time for the student and permit a more thorough coverage of the material. The drawings can serve as a guide to dissection, as well as making possible preparation before class. All of the drawings are easily removable by tearing along a perforated line and can then be inserted in a standard two-ring notebook, rearranged to suit the needs of any course. Additions or alterations can be made by the student where necessary.

GEORGE S. FICHTER
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ANIMAL ENCYCLOPEDIA, by Leo Wender. Cloth. Pages 226. 13×21.5 cm. 1949. Oxford University Press, New York, N. Y. Price $4.50.

Animal Encyclopedia is an alphabetized listing of the mammals of the world, starting with Aardvark and ending with Zwart-wit-pen. With dictionary conciseness, each animal's outstanding features are described—general appearance, color, size, geographical and ecological distribution, economic importance, and scientific name. Synonymy of common names is treated by cross reference, and there are numerous illustrations.

A handy chart at the back of the book gives the gestation periods and the number of young at birth for over one hundred and thirty mammals. This is followed by several pages devoted to classification, with common names used again rather than the scientific. The final thirty pages consist of the scientific names of mammals alphabetized in a column opposite the common name used for the same animal in the main text.

Such a treatment of mammals is certainly not conventional and at first thought might seem to have minimum utility. But it provides a quick reference to over fifteen hundred mammals! Nowhere else can a teacher or student locate as much information on mammals the world over so easily. *Animal Encyclopedia* will surely become a standard reference for every library and every teacher of biology.

GEORGE S. FICHTER

INTERMEDIATE ALGEBRA FOR COLLEGES, by Paul R. Rider, *Professor of Mathematics, Washington University, St. Louis, Missouri.* Pages x+242. Size 21×14 cm. 1949. Macmillan Company, Chicago 16, Illinois. Price $2.75.

This text is simpler in content than Dr. Rider's *College Algebra;* however, much the same presentation is used. Some of the special characteristics of the book are its comments relating algebra to arithmetic, the pointing out of difficulties of language such as the sign (–) used both for minus and negative, the references to basic understandings of the number system, continuity by paragraph references and comments, emphasis on checking results, and summaries of important principles at the end of each chapter.

The material covered is standard. There are sufficient exercises with the answers given to the odd numbered problems. The "worded problems" are taken from life and science as well as being typical textbook problems. In some cases the physical principle is explained just before the problems are given. There are approximately 330 such problems well distributed throughout the text. Factoring is a very short chapter of only eight pages with a list of 90 items to be factored. The idea of a function is presented with graphs, and problems from science are used to fix the idea. In the solution of linear systems, determinants probably hold a more important place than in some texts. It is interesting to note that in relation to rationalizing the denominator the author states on page 9, "There is no advantage, however, in certain particular cases." He goes on to point out that it is wasted time when machines, slide rules, etc., are used. He mentions this again on pages 111 and 127.

It seems to me that the chapter on logarithms is not presented as well as the others. The power of logarithms and their relation to exponents and the slide rule is not stressed sufficiently.

This book is well done and meets the standard set by Dr. Rider in his other texts. It will fill a need now felt by those college students who want or need college algebra and have had a poor high school background in mathematics.

PHILIP PEAK

GENERAL CHEMISTRY, by A. W. Laubengayer, *Professor of Chemistry, Cornell University.* Cloth. Pages xiv+528, 90 tables, 57 figures. 16×23.5 cm. 1949. Rinehart & Co. New York. $4.25.

This book, for college students, will especially appeal to the teachers who prefer the traditional order of topics and are ready to agree to the implication that telling is teaching. The author does an excellent job of telling and will succeed well in holding the attention of those readers whose technical vocabulary of physical science is functional. He does an unusual job of piloting the reader through the development of the science of chemistry keeping him, the while, unconscious of any such thing as the scientific method. He "deduces" laws and principles. One wonders if the scientific method is restricted to deductive logic only.

In the presentation he makes effective use of the graphic; there are, however, no photographic illustrations. The tables are well integrated into the text; the exercises are thought provoking though sparse in number and unduly slanted toward terminology and quantitative relationships. The index is ample. The author, apparently, assumes interest; at least shows slight inclination to bid for it in his treatment. The reviewer would expect the student who is a chemistry major to find much satisfaction in this book's use but would be fearful for the general student who wants more from his chemistry course than a training in scientific logic.

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THE SCIENCE OF CHEMISTRY. George W. Watt, *Professor of Chemistry,* and Lewis F. Hatch, *Associate Professor of Chemistry, University of Texas.* Cloth. Pages viii+567. 16×23.5 cm. Twenty tables; 227 figures. 1949. McGraw-Hill Book Co., New York. $4.50.

This book is planned for students who take first year college chemistry as a terminal course. The authors credit the volume as the product of ten years' experience in teaching students of that description.

Of the thirty-two chapters, twenty-three are devoted to topics of the usual inorganic general chemistry; the last nine are given to organic matter. It is presumed that laboratory work should accompany the study, lecture and class work of the course.

The presentation is essentially inductive in character; most concepts, generalizations and laws follow a recital of experiences or experiments very reasonably within the acquaintance of first year college students. The authors show a continuous recognition of the very probable vocabulary limitations of the students they are trying to instruct.

The teaching aids are limited to drill exercises and a few selected reading references at the end of each chapter; an eight page appendix, a list of problem answers for exercises of a quantitative character and an eight page double column index.

The reviewer suggests: the figures should have fuller legends to make them more valuable to understanding; the publishers should select a quality of paper for the next edition that is less glaring or more comfortable to the eyes of the reader and that the authors introduce a greater consistency in the use of such terms as component, ingredient and constituent when a second printing is made.

Of the few books in print that are geared to the purpose for which this book is intended this is one of the most original and promising that the reviewer has seen. He would expect that students who are permitted to use it would be incited to a growing interest in the science of chemistry. It could be very profitably read by all teachers of high school chemistry as a refresher for improvement of their presentation.

B. CLIFFORD HENDRICKS